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PAPERS PRESENTED AT THE FIRST SHORT COURSE ON HOT WATER AND STEAM HEATING SYSTEMS

HELD AT THE

UNDERGRADUATE DIVISION, UNIVERSITY OF ILLINOIS
NAVY PIER, CHICAGO

SEPTEMBER 9-11, 1947

PRICE: FIFTY CENTS

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CONDUCTED BY
THE DEPARTMENT OF MECHANICAL ENGINEERING
AND THE EXTENSION DIVISION OF THE UNIVERSITY

SPONSORED IN COOPERATION WITH
THE INSTITUTE OF BOILER AND RADIATOR MANUFACTURERS

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UNIVERSITY
OF ILLINOIS
PRESS

FOREWORD

The first Short Course on Hot Water and Steam Heating was offered by the Division of University Extension in cooperation with the Department of Mechanical Engineering and the Institute of Boiler and Radiator Manufacturers.

The purpose of the Short Course was to present an educational program of technical and practical information pertaining to the design and installation of hot water and steam heating systems for residences, for the benefit of dealer-contractors, wholesalers, and manufacturers' representatives.

SHORT COURSE ADMINISTRATION

1947

M. L. Enger, Dean of the College of Engineering
N. A. Parker, Head of the Department of Mechanical Engineering
R. J. Martin, Assistant Professor of Mechanical Engineering
H. C. Rountree, Director of Extramural Classes, University Extension Division

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H. W. Williams, The National Radiator Company
and authors of the papers herein reprinted.

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PROGRAM

TUESDAY, SEPTEMBER 9, 1947

8 A.M.

REGISTRATION: Navy Pier

10 A.M.

WELCOME: On behalf of University — DEAN C. C. CAVENY.

RESPONSE: C. M. BAUMGARDNER, Chairman of the Institute. Introduction of chairmen of I=B=R Committees.

LECTURE: HEAT LOSS CALCULATIONS — PROFESSOR E. A. ALLCUT.

1:30 P.M.

CLASSES: Calculation of heat loss for a room based on:
(a) ASHVE Method.
(b) I=B=R Guide Method.

These calculations will be done as a class, led by the instructor. This will be followed by students making calculations under the I=B=R method for all rooms in the I=B=R Research Home, located on the campus at Urbana, Illinois.

7 P.M.

CLASSES: I=B=R Installation Guide No. 1 will be reviewed in detail by the instructors and will be followed by students completing the calculation of radiation and the design of a one-pipe forced circulation hot water heating system for the I=B=R Research Home.

FORUM: Students from all classes will convene as a forum to have a general discussion of heat loss calculations and installation of one-pipe forced circulation hot water heating systems. Professor Fahnestock, University of Illinois, will act as moderator for this forum and the instructors will form a panel to answer questions.

WEDNESDAY, SEPTEMBER 10, 1947

9 A.M.

LECTURE: FLOW OF FLUIDS — E. C. PETRIE, Assistant Directing Engineer, Valve and Fitting Department, Crane Company.

10 A.M.

CLASSES: Students will calculate and design a two-pipe reverse return gravity hot water heating system, based on I=B=R Installation Guide No. 4 for a two-story residence, using a different plan from that used on the preceding day. These plans will provide for variations in details of wall construction, insulation, etc.

1:30 P.M.

CLASSES: Continuation of calculations, using Guide No. 4.

3:30 P.M.

LECTURE: FACTORS AFFECTING COMFORT — H. F. RANDOLPH.

4:30 P.M.

LECTURE: TYPES, LOCATIONS, AND PERFORMANCE OF RADIATION — PROFESSOR W. S. HARRIS.

DINNER MEETING

6:30 P.M.

ADDRESS: A TRADE ASSOCIATION AT WORK — R. E. FERRY.

ADDRESS: CUSTOMER RELATIONS IN THE HEATING BUSINESS — J. L. ISHAM.

PROGRAM (CONCLUDED)

THURSDAY, SEPTEMBER 11, 1947

9 A.M.

LECTURE: INDIRECT HEATING OF DOMESTIC HOT WATER—PROFESSOR R. J. MARTIN.

10 A.M.

CLASSES: Calculation and design of a steam system, based on I=B=R Installation Guide No. 2, using I=B=R Research Home as plan.

1:30 P.M.

LECTURE: PUMPS AND CONTROLS—S. R. LEWIS.

2:30 P.M.

FORUM: Summary and correlation of subjects covered in the short course, with a question and answer period—L. G. MILLER, Head of Department of Mechanical Engineering, Michigan State College, presiding, assisted by R. J. MARTIN and H. F. RANDOLPH.

4:30 P.M.

PRESENTATION OF CERTIFICATES OF COMPLETION: H. C. ROUNTREE.

I. HEAT LOSS CALCULATIONS

E. A. ALLCUT*

Preamble

Heat losses from buildings are calculated in essentially the same manner as are any other loads, the only difference being in the nature of the load and the units employed. A balance sheet of income and expenditure can be drawn up just as is done in the case of a financial statement, for heat is the equivalent of money and British Thermal Units have to be paid for in dollars.

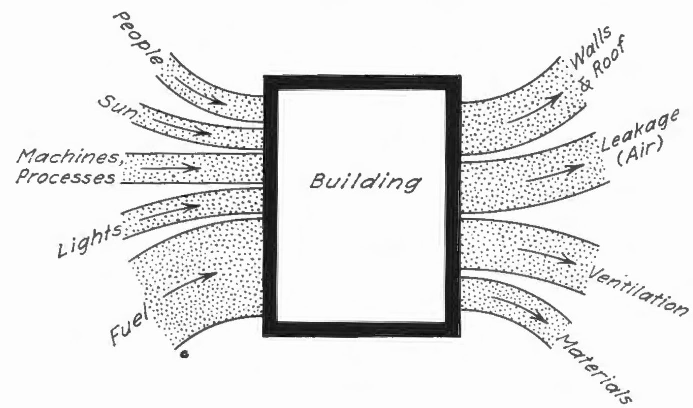

FIG. 1. GAINS AND LOSSES OF HEAT IN A BUILDING

Figure 1 indicates the various items that comprise the heating load. Heat always leaves a building or room through the walls and roof, because a perfect insulator does not exist. Ventilating air enters the building cold and leaves in a heated state. In the case of a warehouse or other storage place, materials are likely to enter the building cold and leave warm. Also, in addition to the air that is purposely supplied for ventilating purposes, air will leak into and out of the building through and around doors and windows, and frequently also through the walls. This infiltration is sometimes relied upon for ventilating purposes, but in the case of large buildings, ventilating air must be supplied in definite amounts and in the right places, as air leakage is likely to be erratic, in both quantity and direction. On the credit side, heat is received from people in the building, the quantity varying

* Professor, and Head of the Department of Mechanical Engineering, University of Toronto, Toronto, Ontario, Canada.

from 400 to 800 B.t.u. per hr. per person under different circumstances. Some heat is usually received from the sun, and any mechanical or electrical energy supplied for machines, processes or lights is converted into heat and reduces the heating load to a corresponding degree. The difference between the totals of outgoing and incoming heat, therefore, constitutes the net heating load, and the saving made possible by insulating walls or roof will consequently vary considerably under different circumstances. It is uneconomical to spend a lot of money to insulate the walls and roof, if most of the heat loss takes place elsewhere, because of air leakage. This is the reason why rule-of-thumb methods seldom work out satisfactorily, and why heat losses must be calculated systematically and in detail.

The following observations, therefore, relate to the principles that govern the flow of heat through a solid barrier of any kind, when there are fluids of different temperatures on the two sides of the barrier. In the case of a building, the barrier consists of the walls, windows and doors; the fluids are warm air inside and cold air outside the structure, respectively.

Resistances

There is a close parallel between the factors affecting heat loss calculations and those in other branches of engineering. In the case of an automobile (Fig. 2) the horsepower available from the engine rises to a maximum at a definite speed and then begins to fall off. On the other hand, the power required to overcome the wind and road resistance (lower curve) increases with the speed, and the power available for acceleration is the difference between these two quantities. In the example given, the curves cross at about 3000 revolutions per minute, or about 67 mi. per hr., and beyond that point no further acceleration is possible. The resistance encountered, therefore, is the controlling factor. The same sort of thing occurs when fluids flow through a pipe. Figure 3 shows the relative resistances of a straight pipe 10 ft. long, a straight pipe 50 ft. long, and a pipe 50 ft. long with right-angle bends. The horsepower required to deliver 20,000 cu. ft. of free air per min. increases as the resistance increases. The flow of electricity also follows a similar law, known as Ohm's Law, in which the current passing around a circuit is shown to decrease as the resistance increases, if the voltage remains constant (Fig. 4).

Applying the same reasoning to the flow of heat through a wall, the impelling force that causes the heat to flow is the temperature differ-

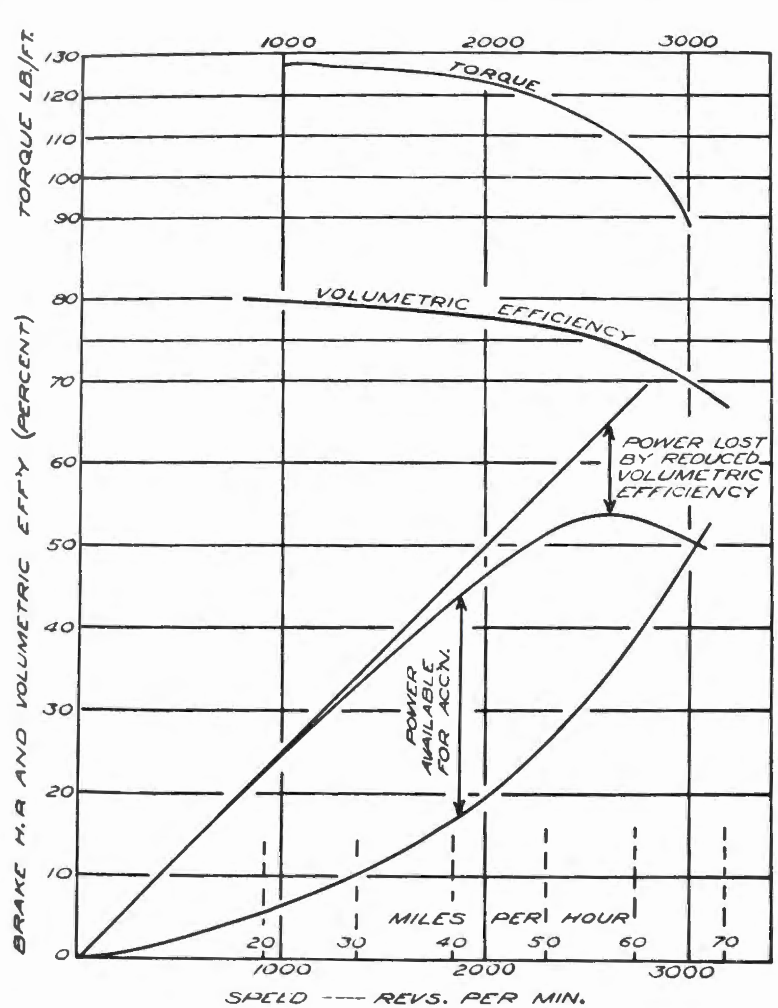

FIG. 2. COMPARISON BETWEEN THE POWER AVAILABLE FOR DRIVING AN AUTOMOBILE AND THE RESISTANCE TO MOTION. THE DIFFERENCE IS THE POWER AVAILABLE FOR ACCELERATION

ence between the inside and outside of the wall, and the quantity of heat (B.t.u.) that will flow depends on that difference in temperature and on the resistance encountered. Materials that offer a high resistance to the flow of heat are called *insulators*, and those that offer a low resistance are called *conductors*. The same kinds of calculations

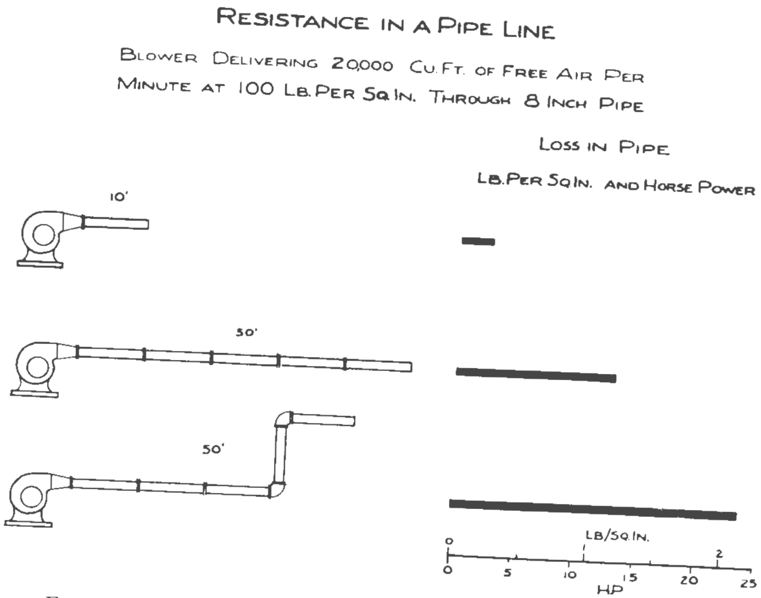

FIG. 3. COMPARATIVE RESISTANCES TO THE FLOW OF AIR THROUGH A PIPE AND THE POWER REQUIRED TO OVERCOME THEM

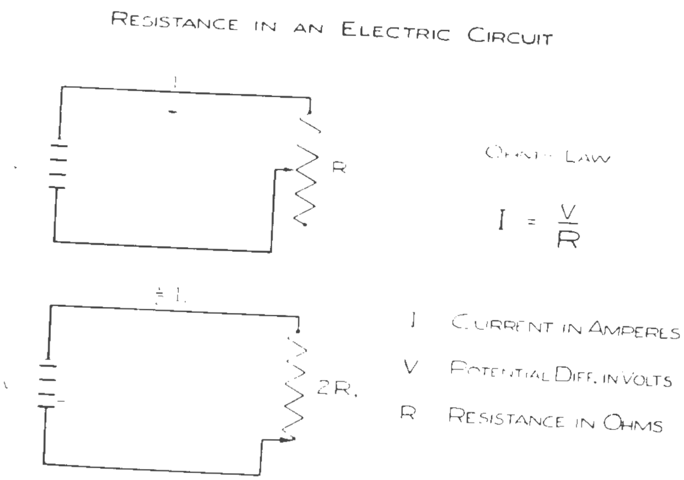

FIG. 4. RESISTANCE IN AN ELECTRIC CIRCUIT AND THE LAW THAT DETERMINES THE FLOW OF CURRENT

are made irrespective of whether we want to encourage or to discourage the transmission of heat, as the same laws apply in both cases. For design purposes it is convenient to use certain standard temperatures which vary with the location of the building and its intended purpose. A common assumption is the maintenance of a temperature of 70 deg. inside the building when the temperature outside is zero, giving a temperature difference of 70 deg. If the actual temperature difference for the building in question is 85 deg., the heat flow will be increased in the ratio $\frac{85}{70}$; that is an increase of about 21 per cent above standard conditions. Correction factors are frequently tabulated to facilitate calculations for different design temperatures.

The Transmission of Heat

Heat is transmitted in one or a combination of three ways. Conduction consists of the vibration of the molecules or particles of the material through which the heat is passing. These particles remain in fixed relative positions, as in the case of heat passing from one end of a metal bar to the other. Metals are usually good conductors because their resistances are low, and liquids, vapors or gases (except mercury) are bad conductors and good insulators. However, if the liquid or gas is able to move, heat is transmitted by its circulation. This phenomenon is called convection, and it is a very effective way of transmitting heat under suitable circumstances. Circulation in a boiler is a good example of convection. Radiation, on the other hand, operates in straight lines through a gas or vapor, in a manner somewhat similar to the transmission of light. It casts shadows just as light does and, under suitable circumstances, is a most efficient way of transmitting heat, as in the case of a boiler furnace, or radiant heating in a room. For convenience, however, in dealing with the transmission of heat through a wall, all of these factors are frequently lumped together and treated as conduction. An example of this is the case of a hollow tile, where all three methods play some part in the process.

The units employed may be indicated by considering the case of a solid material, as illustrated in Fig. 5. Consider 1 sq. ft. of the material, 1 in. thick, with a temperature difference of 1 deg. F. on its two sides. The number of B.t.u. that will pass through this material is called the conductivity or k factor (a). If the thickness is increased to x inches (b), the amount of heat transmitted then becomes k x.

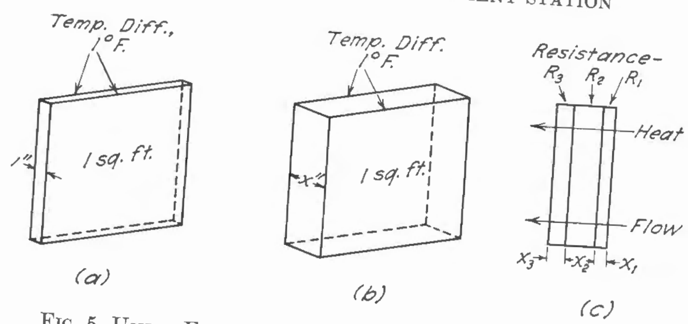

FIG. 5. UNITS EMPLOYED IN CONDUCTION: (a) CONDUCTIVITY, (b) CONDUCTANCE, (c) RESISTANCES IN SERIES

This is called the conductance C, and the resistance R is equal to $1/C$. Therefore, if three materials of thicknesses x_1, x_2, and x_3, respectively, are added together and the heat passes through them as in (c), the total resistance is $R_1 + R_2 + R_3$ and the heat transmitted through the composite wall per degree of temperature difference will be $\frac{1}{R_1 + R_2 + R_3}$. The heat loss through any kind of structure — wall, window, or door — can thus be calculated by adding together the resistances of its various components.

In practice, most of these resistances are calculated from the conductivity (k) or conductance (C) of the material in question. These are obtained experimentally by the hot plate or hot box methods (Fig. 6).

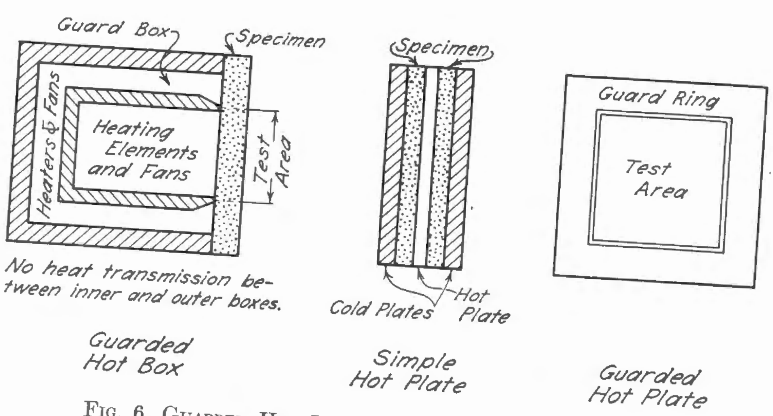

FIG. 6. GUARDED HOT BOX AND HOT PLATE METHODS OF MEASURING HEAT TRANSMISSION

The hot plate test is carried out by sandwiching two pieces of the material to be tested between a central plate that is electrically heated and two other plates that are cooled by water or brine. The hot plate is usually surrounded by a guard ring which is separately heated to counteract the effect of heat losses through the edge of the specimen, so that only the central test area is actually employed for experimental purposes. Thermocouples are used to measure the temperature differences between the hot and cold sides of the specimen, and the conductivity (k) is calculated from the amount of electrical energy supplied. A complete wall section may be tested by means of the hot

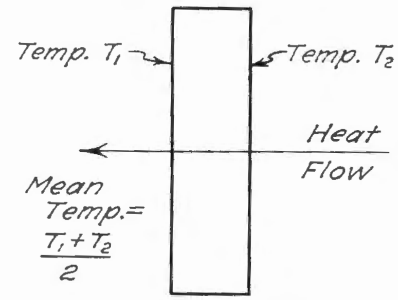

FIG. 7. MEAN TEMPERATURE

box method, which is similar to the hot plate test, save that in this case there is hot air on one side of the specimen and cold air on the other side. This has the advantage of reproducing the actual conditions of use, but the specimens and apparatus are large and expensive, the tests are comparatively lengthy, and the results obtained depend quite considerably on workmanship and freedom from leakage. It is more usual and convenient, therefore, to calculate and combine resistances from conductivities obtained by means of the hot plate tests. These are the figures usually given in the standard tables and books of reference.

Effect of Variables

In making comparisons, however, it is necessary to be sure that the test figures employed were obtained under the same conditions. In most instances, the value of k is given for a certain mean temperature, which is the sum of the temperatures on the hot and cold sides divided by two (Fig. 7).

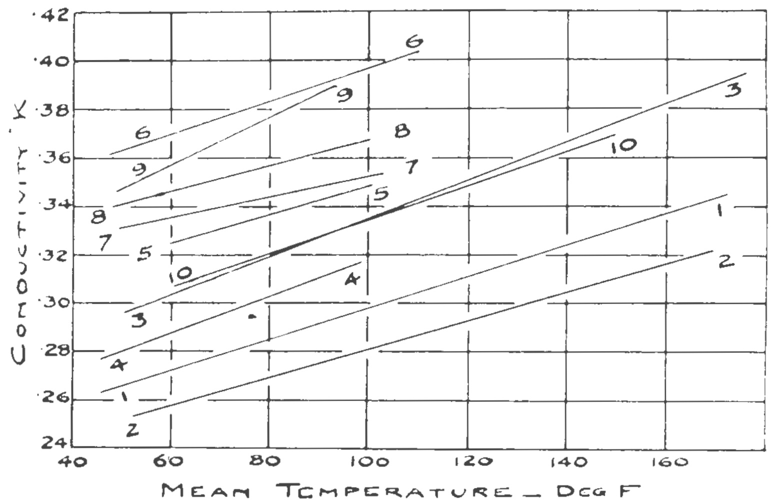

FIG. 8. CONDUCTIVITIES OF VARIOUS INSULATING MATERIALS AT DIFFERENT MEAN TEMPERATURES

The curves in Fig. 8 show how the conductivities of some of the common insulating materials vary with changes of mean temperature. It will be observed that the conductivity in each case increases as the mean temperature increases, but that the rate of increase is fairly even for these materials, because the lines are very nearly parallel to each other. Consequently, if two materials are being compared and their

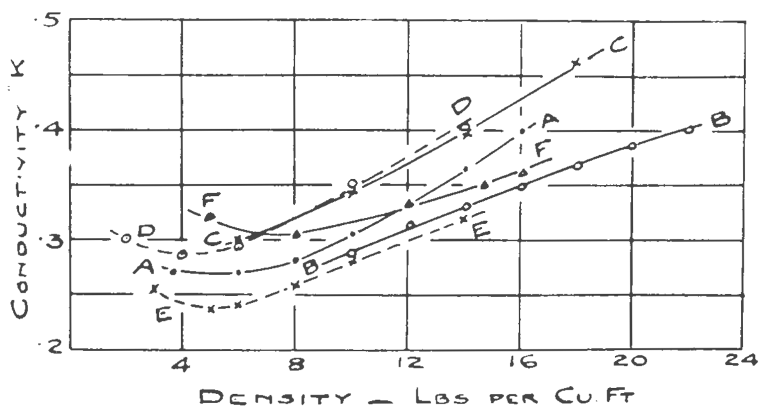

FIG. 9. EFFECT OF DENSITY ON CONDUCTIVITY

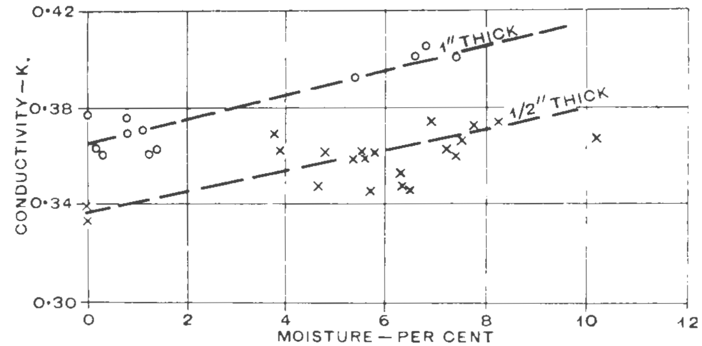

FIG. 10. CONDUCTIVITIES OF FIBER BOARDS WITH VARIOUS PERCENTAGES OF MOISTURE

conductivities are given at different mean temperatures, approximate corrections may be made by using an average rate of increase as shown in Fig. 8.

The density of the material is also important (Fig. 9). Here it is evident that the conductivity decreases as the material becomes denser up to a certain point, and beyond that point the conductivity increases as the density rises. The reason for this is, probably, that at the very low densities, some circulation of air (convection) takes place inside packed materials, and this increases the heat loss.

Moisture is an extremely important factor because it not only increases the conductivity (Fig. 10) but, by condensing inside the wall and possibly freezing there, causes considerable trouble in the structure and decoration of the building. The influence of moisture is difficult to measure directly because, while water may be added to a specimen that is being tested, it does not remain uniformly distributed throughout the material but rather tends to leave the hot side and collect on or near the cold side. However, its effects are known to be so serious that care must be taken to avoid its absorption, by adding a vapor-proof barrier to the warm side of the wall. It is also advisable, where possible, to provide a small amount of ventilation on the cold side, so that any moisture that does penetrate into the wall may have an opportunity of evaporating when the conditions become favorable.

In general it is assumed that the conductance C decreases as the thickness increases, and that an insulator 4 in. thick has four times the resistance of a 1-in. thickness of the same material. This is not

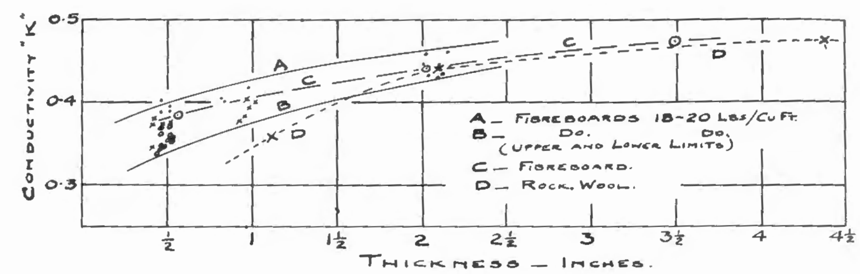

FIG. 11. TEST RESULTS ON INSULATING MATERIALS OF DIFFERENT THICKNESSES

always true, however, as is shown by the curves in Fig. 11, which gives the results of a large number of tests made on different thicknesses. Here rising conductivities with increasing thickness indicate that the resistance does not increase in direct proportion to the thickness and that the resistance of a 4-in. thickness may be only about 3½ times that of a 1-in. thickness. A possible explanation of this is indicated by the curves in Fig. 12, in which the line drawn through the resistances of fiber boards of different thicknesses does not go through the zero point. This appears to indicate that there is some resistance left when there is no thickness. The only reasonable explanation of this observation is that the surface itself offers a certain amount of resistance to the transmission of heat. The form of conductivity curve k obtained by calculations from the resistance curve agrees fairly well with the average conductivity curves obtained by experiment, as shown in Fig. 11.

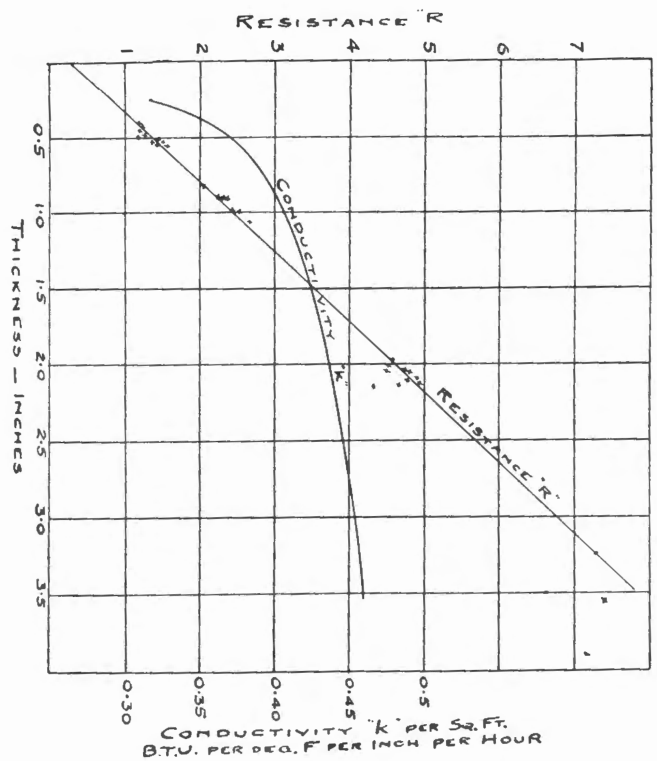

FIG. 12. CALCULATION OF VALUES OF k FROM RESISTANCE CURVE

(Note that some resistance remains when the thickness is zero)

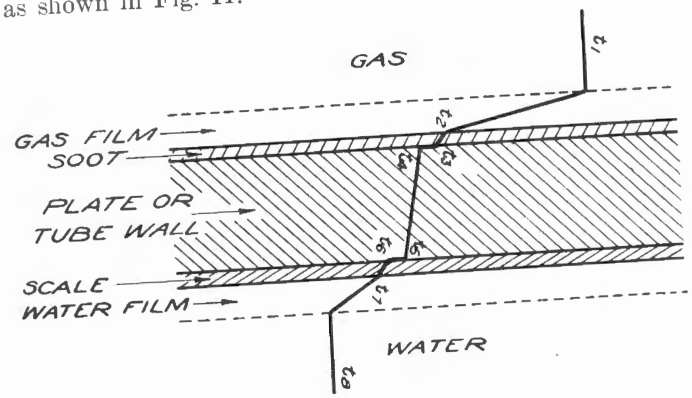

FIG. 13. FILM RESISTANCES, EXEMPLIFIED BY THE TRANSMISSION OF HEAT FROM GAS TO WATER

Film Resistances

The addition of fluid films to a solid barrier is shown by the curve in Fig. 13. This example applies specifically to the transmission of heat between gas and water in a boiler, but the principle applies to any other case where heat is transmitted from one fluid to another. The example shows that there is a temperature drop $t_1 - t_2$ in a film of gas that clings to the hot side of the plate, and a similar temperature drop, $t_7 - t_8$, in the film of water on the cooler side of the plate. It has been pointed out already that gases and liquids are bad conductors and, *if kept still*, offer considerable resistance to the transmission of heat. The fact that these fluid layers are stagnant means that they are good insulators and, therefore, the film resistance on both sides of the solid barrier must be added to the resistance of the solid material itself. The film conductance, f, increases as the thickness of the fluid film decreases and therefore the effectiveness of this blanket is reduced by increases of gas or water velocity. This is illustrated by Fig. 14, in which the conductance f of a film of air is shown to increase in direct proportion to the speed of the air passing across the surface. The practical effect of this is that heat losses on a windy day are greater

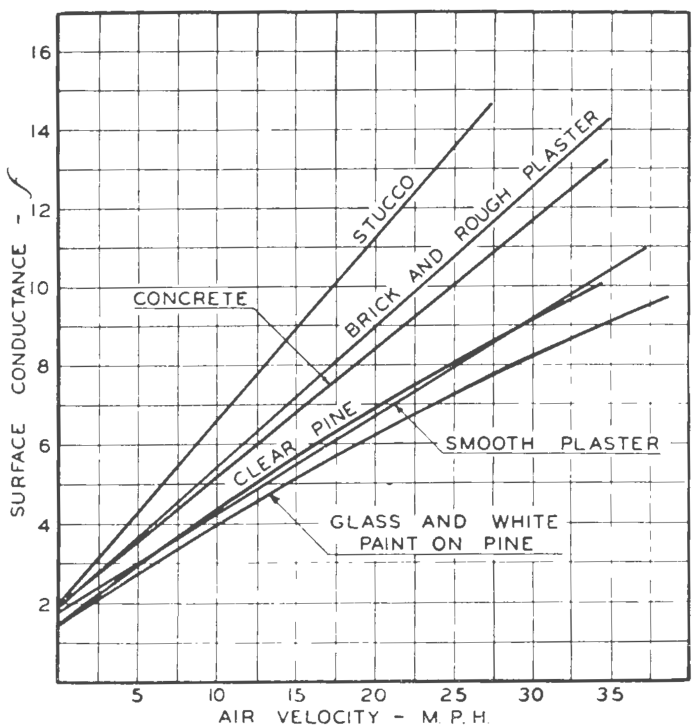

Fig. 14. Increase of Film Conductance as the Air Velocity over a Surface Increases (Rowley and Algren)

than those on a calm day, because the thickness of the air blanket on the outside of the wall is reduced by the wiping effect of the wind. An example of what happens under these conditions is shown in Fig. 15. In this case the temperatures of the air inside and outside a frame structure were 72.5 deg. and 2.5 deg. F. respectively, but an increase in the speed of the air on the cold side reduced the outside temperature of the siding from 14 deg. to 8 deg. F., and the inside surface of the

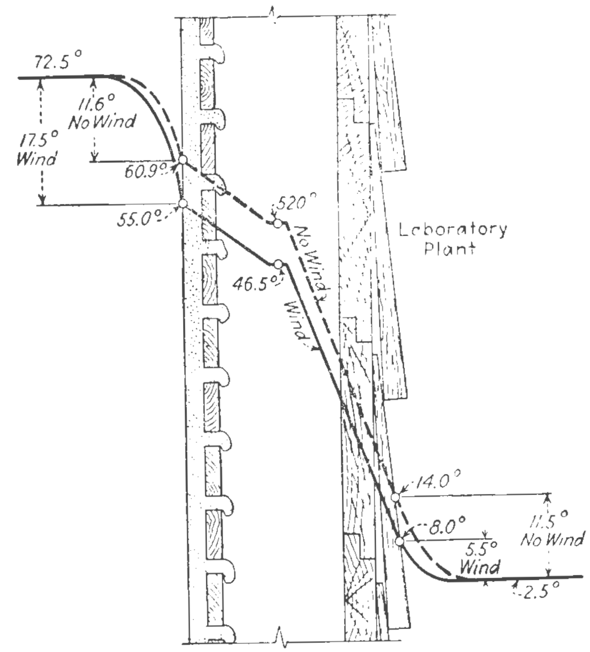

Fig. 15. The Effect of a Wind in Reducing the Outside and Inside Surface Temperatures

plaster from 60.9 to 55 deg. F. This decrease of the inside temperature would affect considerably the comfort of the occupants of the building.

Internal Structure of Material

It has already been pointed out that gases are very bad heat conductors provided that they can be kept stationary; in fact, most heat insulating materials depend for their effectiveness on the air that is contained within them. Such materials therefore consist essentially of air that is entangled in sufficient fibrous or other suitable material of poor conductivity to keep the air still. The structure of an insulating material, therefore, is a matter of considerable importance, and Fig. 16 indicates the kinds of structure that are commonly used for this purpose. A consists of fibers in parallel formation (as in fiber boards), B and C are lattice formations, D is a random structure (as in rock wool), E consists of solid or other powdered materials surrounded by air, and F is a cellular structure similar to that existing in cork (Figs. 17 and 18).

It is suggested that, just as a metallurgist aims at a certain type of structure which will give the physical properties required, so the manufacturer of insulating materials should aim at a structure that will combine the maximum amount of *still* air with the minimum amount of solid material. Obviously, if the air cells are connected to

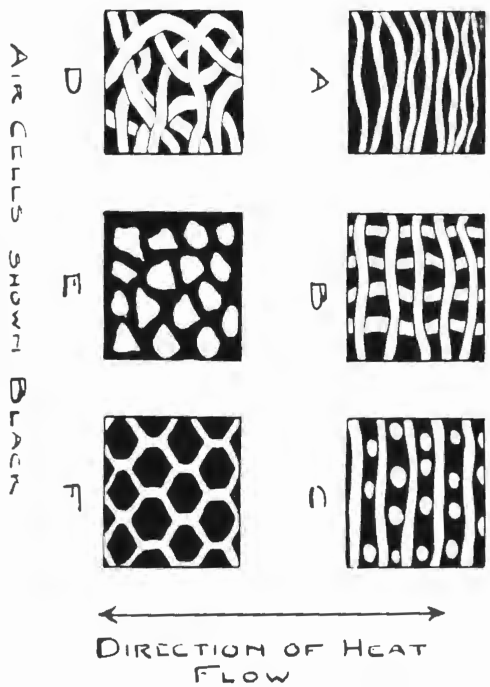

FIG. 16. INTERNAL STRUCTURES OF INSULATING MATERIALS:
A. PARALLEL FIBROUS STRUCTURE; B. AND C. LATTICE STRUCTURE; D. RANDOM STRUCTURE; E. POWDERED STRUCTURE; F. CELLULAR STRUCTURE

give a free path, as in A and E, internal fluid friction will be an important factor in controlling the amount of air circulation within the material.

These air cells are very small and therefore the amount of circulation within them is not serious. Large air cells, however, as in the case of hollow tiles and the spaces between double windows, are in a different category. Here conduction plays a minor part and most of the heat is transmitted by radiation and convection. For convenience, the heat transmission across such cells is usually expressed as conductance.

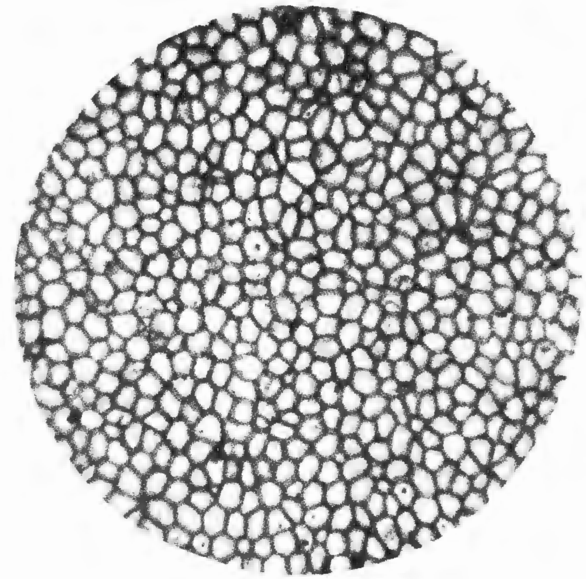

FIG. 17. THE CELLULAR STRUCTURE OF CORK (ARMSTRONG CORK COMPANY)

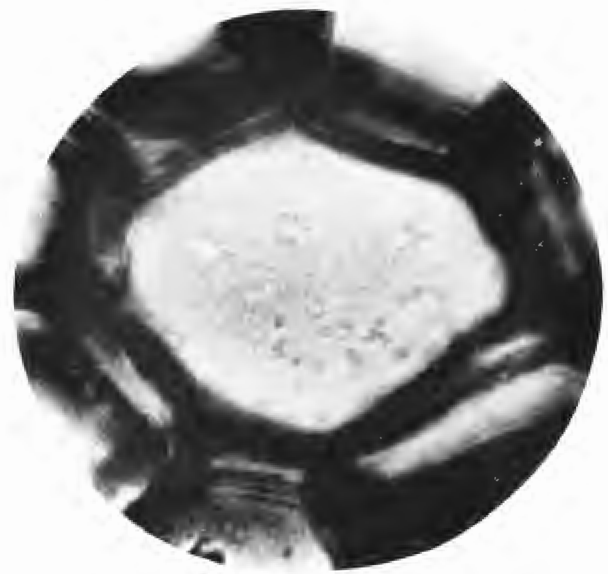

FIG. 18. ONE CELL OF CORK, HIGHLY MAGNIFIED (ARMSTRONG CORK COMPANY)

Results obtained by Rowley and Algren at the University of Minnesota show that, as the thickness of the air space increases, the conductance becomes less at all mean temperatures between 20 and 150 deg. F., until the air space is approximately ⅞ in. wide (Fig. 19).

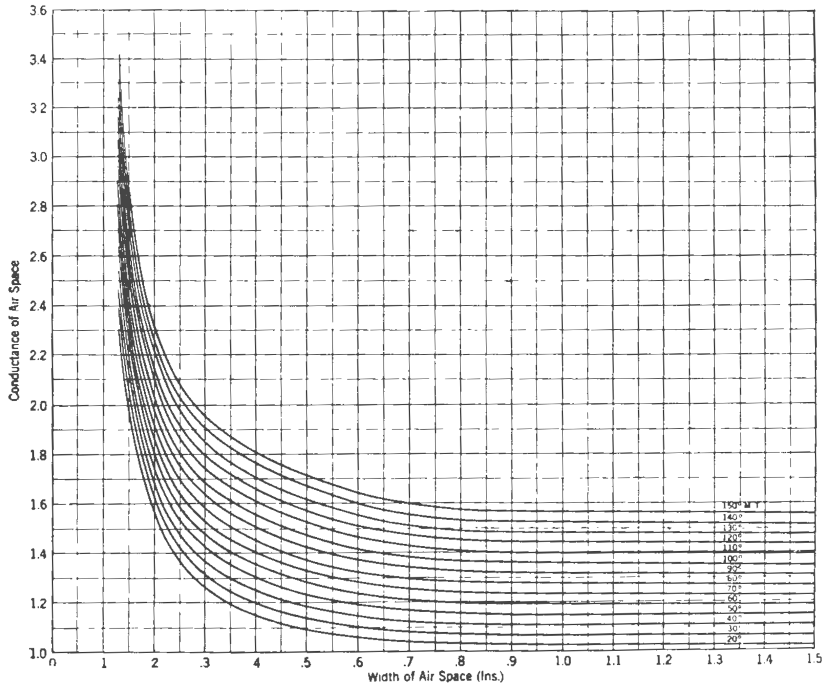

FIG. 19. CONDUCTANCES OF AIR SPACES (ROWLEY AND ALGREN)

Beyond that, any additional thickness does not add to the insulating value. It is therefore preferable (Fig. 20) to divide wide air spaces into a number of narrower ones. A shows the manner in which the air circulates from the hot to the cold side of a hollow tile. B indicates the manner in which this circulation is slowed or stopped by filling the center of the tile with powdered material. C illustrates the principle of having three narrow air spaces instead of one wide air space, thus increasing the resistance to heat transfer.

The same principle may be applied with bright metal foil, which forms a trap for *radiant* heat. With ordinary aluminum foil about 96 per cent of the radiant heat will be intercepted by a single sheet, but the convected heat will still be transmitted, and therefore a number

of parallel sheets are employed as in D to give a series of heat traps, thus increasing the effectiveness of the barrier. The best spacing has been found to be about three sheets per inch of thickness. As the parallel arrangement shown in D is difficult and expensive to employ, the crumpled foil arrangement shown in E may be substituted. This also divides the large air space into a number of small ones. It is not quite

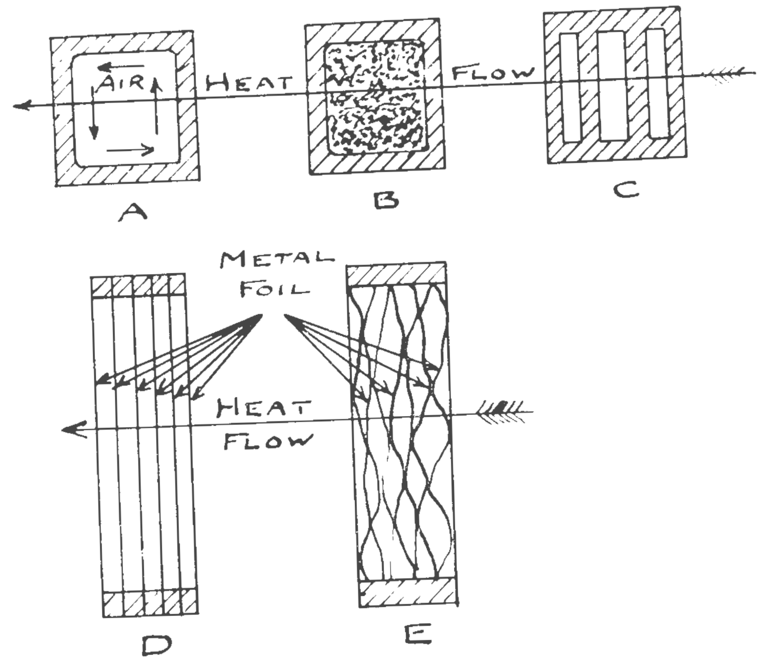

FIG. 20. VARIOUS ARRANGEMENTS OF LARGE AIR SPACES

so effective as the arrangement shown in D but is considerably more convenient and is most generally employed in practice.

It must be remarked that these sheets or surfaces remain effective only so long as their surfaces are bright. Figure 21 illustrates the effect of increasing thicknesses of oxide on the emissivity of aluminum. Thus, the bright surface emits only about 3 to 4 per cent of the radiant heat received, whereas if the surface is covered with an oxide coating $\frac{24}{100{,}000}$ in. thick, the heat emitted is 75 per cent of that received. This means that its effectiveness as an insulator is reduced from 96 per cent to 25 per cent. If the surface is protected by a layer

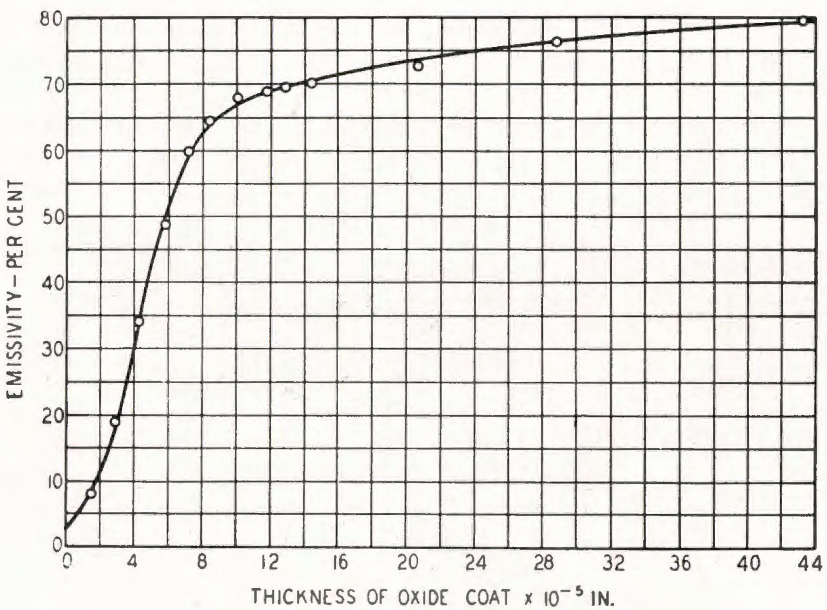

FIG. 21. EFFECT OF VARIOUS THICKNESSES OF OXIDE COATING IN REDUCING THE INSULATING VALUE OF ALUMINIUM FOIL (MASON)

of lacquer, either clear or colored, the same general effect is produced, and a coating of lacquer $\frac{24}{100{,}000}$ in. thick reduces the effectiveness of the surface to half that of the bare metal (Fig. 22).

Air Leakage

The question of air leakage was touched upon briefly at the beginning of this lecture. Many insulating materials having structures as shown in Fig. 16 A–E are porous to the passage of air, and the more porous they are, the greater is the heat loss. Figure 23 indicates the amount of air leakage through fiber boards of different thicknesses when exposed to different wind pressures. It will be seen that the leakage is independent of the thickness of the board and that the leakage curves arrange themselves in order of density. Thus, a light thick board may actually transmit more air than a dense, thin one. Low density is usually an advantage from the standpoint of conductivity, but it may be a disadvantage from the standpoint of air leakage. Figure 24 gives the results obtained when a plain fiber board was painted on one side with two and three coats of aluminum paint

respectively. By this means, leakage was reduced to about one-fourth of its previous value. A continuous coating of aluminum foil stopped the leakage entirely.

The question of cracks around doors and windows, or from cracking in the construction generally, must also be taken into account when

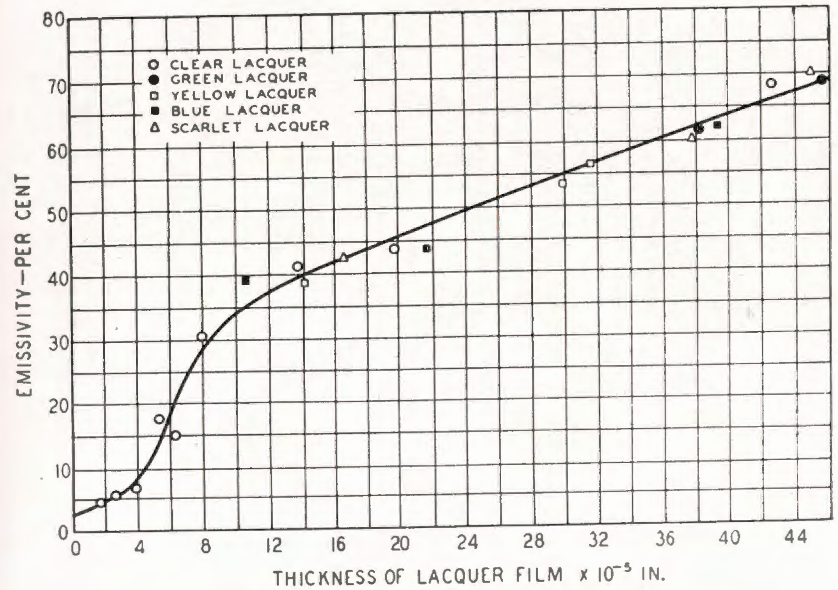

FIG. 22. EFFECT OF LACQUER ON THE INSULATING VALUE OF ALUMINIUM FOIL (MASON)

considering the question of air leakage. A crack is really a long, thin hole and therefore the general laws which relate to the flow of air through an orifice also apply to leakage of air through a crack. In some codes this method is used for the purpose of calculating the air leakage loss. Tables for this purpose are given in the Guide of the American Society of Heating and Ventilating Engineers.

The foregoing are the various factors that affect resistance to heat transfer. By adding all of these resistances together (Fig. 25) we obtain the total resistance of the wall, including the air film on each side of it. From this sum the coefficient of heat transfer (U) may be calculated. The latter is then multiplied by the temperature difference between the two sides of the wall to obtain the heat loss factor which, when multiplied by the wall area, gives the total heat loss in B.t.u. per hr. for that part of the construction. In some instances, as

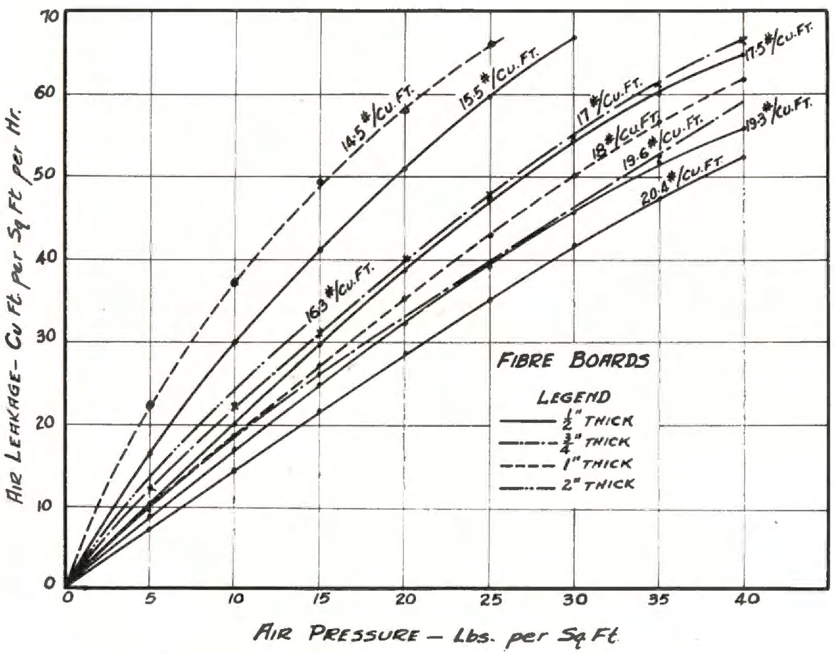

FIG. 23. EFFECT OF THICKNESS AND DENSITY ON THE PASSAGE OF AIR THROUGH FIBER BOARDS

in the case of doors and windows, the intermediate resistances are so small as to be negligible, and therefore the total resistance is considered to consist of the two air films of conductances f_1 and f_2, respectively, on either side of the door or window. In that case $U = \dfrac{1}{\dfrac{1}{f_1} + \dfrac{1}{f_2}}$. For parts of the structure that are below ground level, there is an air film on one side only and therefore only the inside air film has to be taken into account.

Thus, by dividing the total structure into a number of areas, each of which comprises a particular kind of construction, the total heat loss for the building, and therefore the amount of fuel required to heat it, may be calculated. This procedure would appear to be long and tedious but, by using the standard calculation forms issued for the purpose, reliable results can be obtained and errors incidental to making shortcuts will be avoided.

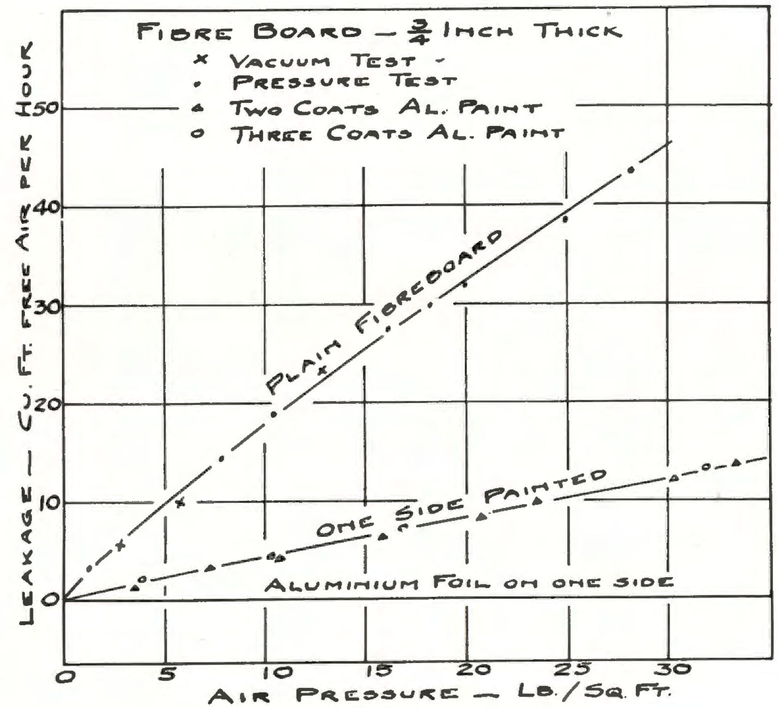

FIG. 24. THE PROTECTION OF FIBER BOARDS AGAINST AIR LEAKAGE

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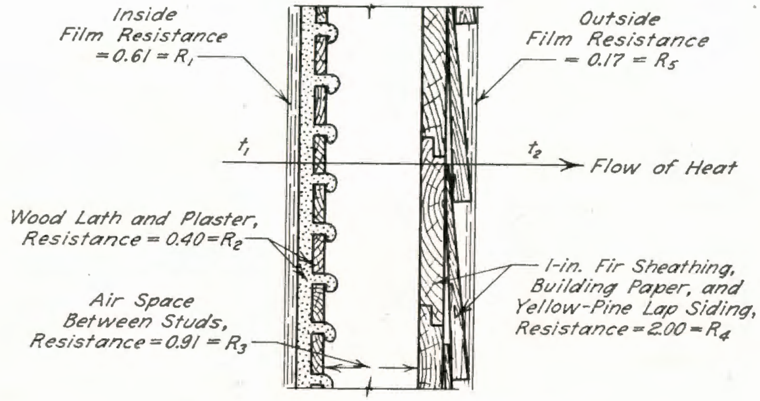

Thermal Resistances for Frame Wall

Total Resistance $= R_1 + R_2 + R_3 + R_4 + R_5$

$$U = \frac{1}{R_1 + R_2 + R_3 + R_4 + R_5}$$

Heat Loss Factor $= U(t_1 - t_2)$

B.t.u. Loss = H.L.F. X sq. ft.

Fig. 25. Resistances in a Frame Wall

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II. FLOW OF FLUIDS THROUGH PIPE

E. C. PETRIE*

One of the most widely investigated subjects in industry is the manner in which fluid flows through pipe. Any industry which depends upon fluid power for its sustenance is vitally interested in the accurate determination of the pressure drop caused by the passage of fluids through pipe. The economics involved in the proper selection of the correct pipe size, the most suitable pump, the most efficient piping layout are best determined when accurate methods are used to calculate pressure drop.

Many empirical formulas have been proposed for the solution of pressure drop problems, but these are often extremely limited and can be applied only when the conditions of the problem closely approach the conditions of the experiments from which these formulas were derived. Because of the great variety of fluids being handled in modern industrial processes, the advantages of a single equation which can be used for the flow of any fluid in pipes are obvious. Such an equation is the Fanning formula. The Fanning formula can be derived rationally by means of dimensional analysis; however, one variable in the formula, the friction factor, must be determined experimentally.

Fanning Formula

The Fanning formula may be expressed in the following convenient forms:

$$\Delta P = \frac{.00000336 f L W^2}{d^5} = \frac{.000215 f \epsilon L Q^2}{d^5}$$

or

$$\Delta P = \frac{.00129 f \epsilon V^2 L}{d},$$

where

ΔP = pressure drop, lb. per sq. in. per ft. of pipe
W = rate of flow, lb. per hr.
Q = rate of flow, gal. per min.
V = velocity in ft. per sec.
ϵ = density, lb. per cu. ft.
d = inside diameter of pipe, in.
L = length of pipe, ft.
f = friction factor.

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It can be observed in examining this formula that all terms are readily obtainable except the value of f. This term must be based upon experimental results and is primarily a function of the condition of the pipe wall — that is, whether it is rough, smooth, tubular, corroded, etc., the rate of flow, the diameter of the pipe, and the type of fluid.

Nature of Flow in Pipes

By performing a simple experiment it can readily be shown that there are two entirely different types of flow in pipes. The experiment consists of injecting small streams of a colored fluid into a fluid flowing in a glass pipe and observing the behavior of these colored streams at different sections downstream from their points of injection. If the velocity of the main stream is varied, it can be observed that the streams of colored fluid flow in straight paths when the velocity is low. As the velocity is increased, however, the filaments show a tendency to break up at a certain "critical" velocity. This "critical" velocity varies for different types of fluid, gases having a relatively low value while liquids have values much higher, depending upon their viscosity. At higher velocities the filaments no longer flow in straight paths, but are dispersed at random throughout the main body of the fluid. Figure 1a illustrates the behavior of the filaments at low velocities, while Fig. 1b and Fig. 1c show their behavior at higher velocities.

The type of flow which exists at velocities below the "critical" is known as viscous or streamline flow. The velocity of the fluid is greatest at the pipe axis and decreases sharply to zero at the pipe wall.

At velocities greater than the "critical" the flow is turbulent. Even though a turbulent motion exists throughout the greater portion of the pipe diameter there is always a thin layer at the pipe wall which is moving in viscous flow.

Reynolds Number

Numerous experiments, as well as theoretical considerations, have shown that the nature of flow in pipes depends upon a value known as the Reynolds number which can be obtained by solving the following dimensionless equation.

$$R = \frac{124 d V \epsilon}{\mu} = \frac{50.7 Q \epsilon}{d \mu} = \frac{6.32 W}{d \mu},$$

where
- R = Reynolds number
- d = inside diameter of pipe, in.
- W = rate of flow, lb. per hr.
- V = velocity of fluid, ft./sec.
- Q = quantity of flow, gal. per min.
- ϵ = density of fluid, lb. per cu. ft.
- μ = absolute viscosity, centipoises.

FIG. 1. BEHAVIOR OF THE FILAMENTS AT LOW VELOCITIES (a) AND AT HIGHER VELOCITIES (b AND c)

The flow is viscous for Reynolds numbers less than 1200 and turbulent for Reynolds numbers greater than about 2200. Between these two values lies a transition region in which the flow may be either viscous or turbulent, depending upon the condition of the flow as it enters the pipe section under consideration and, to a certain extent, upon the roughness of the pipe walls.

Friction Factor

As would obviously be expected, there is an empirical relationship between Reynolds number and the friction factor f used in the Fanning formula. Probably the most complete and reliable data upon friction factors for the general flow equation (Fanning's formula) are given by R. J. S. Pigott[1] and Emory Kemler.[2]

Figure 2 shows the relationship between Reynolds number and friction factor. The transition range between viscous and turbulent flow can be readily observed between Reynolds numbers of 1200 and approximately 2200.

You may logically ask, "How can this general flow formula be applied in the design of a heating system?" The flow is generally slow in all but the forced circulation type; there are many fittings and valves in any piping installation which would materially affect flow; the effect of temperature changes may be a serious factor, etc.

Before delving into a specific example, let us review the subject of how valves and fittings affect fluid flow. Quite logically, the resistance offered by valves and fittings cannot be determined exactly for all installations, because of the variety of types currently used. For this reason it is necessary to adopt an average resistance value for the various designs based upon tests which have been conducted by competent investigators. For simplicity of application, the IBR has incorporated in its publications values for the resistance of valves and fittings expressed in terms of pipe length or elbow equivalents. For example, the resistance of a ¾-in. globe valve is equivalent to the same resistance as 18 feet of ¾-in. standard pipe or twelve ¾-in. elbows. Therefore, if the resistance of a ¾-in. pipe line 10 ft. long containing one globe valve is to be determined, the pressure drop caused by 10 + 18 or 28 ft. will produce the desired answer.

[1] "The Flow of Fluids in Closed Conduits." Mech. Eng., August, 1933.
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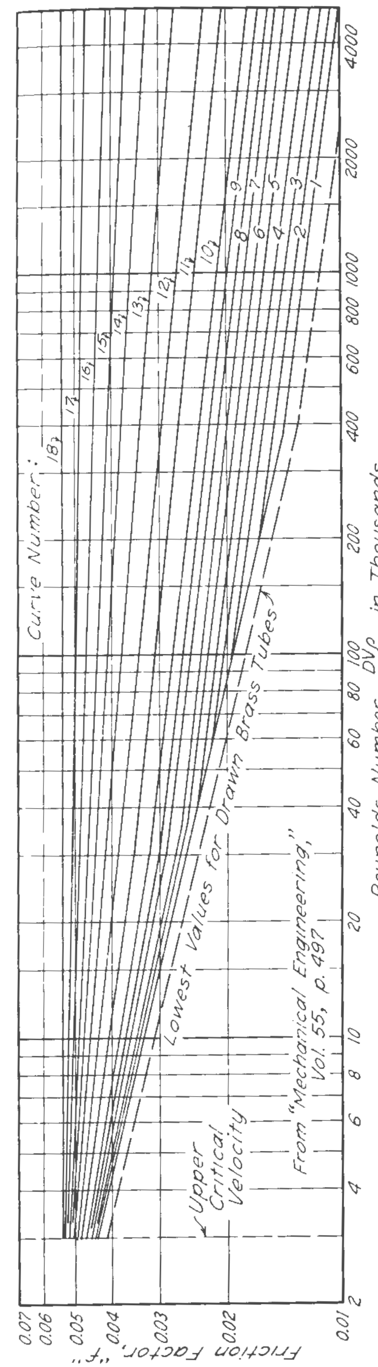

Type of Conduit	Curve Number in Diagram Above																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Drawn Tubing-Brass, Tin, Lead, Glass, Diameter in Inches →	0.35 up	—	—	—	—	—	—	—	—	—	—	—	—	0.125	—	—	—	0.0625
Clean Steel, Wrought Iron Diameter in Inches →	72	48-66	14-42	6-12	4-5	2-3	$1\frac{1}{2}$	$1-1\frac{1}{4}$	$\frac{3}{4}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{1}{8}$	—	—	—	—	—
Clean Galvanized Iron Diameter in Inches →	—	—	30	10-24	6-8	3-5	$2\frac{1}{2}$	$1\frac{1}{2}-2$	$1\frac{1}{4}$	1	$\frac{3}{4}$	$\frac{1}{2}$	—	$\frac{3}{8}$	—	$\frac{1}{4}$	—	$\frac{1}{8}$
Best Cast Iron, Cement, Light Riveted Sheet Ducts Diameter in Inches →	—	—	48-96	20-48	12-16	5-10	3-4	$2-2\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{4}$	1	—	—	—	—	—	—	—
Average Cast Iron, Rough Formed Concrete Diameter in Inches →	—	—	96	42-96	24-36	10-20	6-8	4-5	3	—	—	—	—	—	—	—	—	—
First-class Brick, Heavy Riveted Steel Diameter in Inches →	—	—	220	84-204	48-72	20-42	16-18	10-14	8	5	4	3	—	—	—	—	—	—

Note—In drawn tube actual diameter is given. In pipe nominal size of standard weight is given

FIG. 2. FRICTION FACTOR CHART

The following table (taken from IBR Installation Guide Number 1) gives the equivalent length in feet of pipe for various types of valves and fittings.

Size of Main	90° Ell	45° Ell	Sq. Head Cock	Globe Vlv.	Gate Vlv.
¾"	1.5	1.0	1.0	18	1.0
1"	2.0	1.5	1.0	24	1.0
1¼"	2.5	2.0	1.5	30	1.5

Determination of Friction Head in Pipes

To illustrate the adaptation of the Fanning formula to flow of water in pipes and to point out the advantage of using the simplified data which have been published in the IBR Installation Guides, let us calculate the pressure drop value for a certain condition of flow.

In Table 10, page 27, of Installation Guide Number 4 covering two Pipe Reverse Return Gravity Hot Water Systems, friction heads in milinches per ft. of pipe are listed for various loads and pipe sizes for a condition wherein the temperature through the radiator drops 30 deg. F.

Let us assume the following conditions:
Load, B.t.u./hr. = 10,000
Average radiator temp. = 170 deg.
Pipe size = ¾ in. standard
Friction head per data in Table 10 = 19 milinches/ft.

The Fanning formula takes the following form:

$$\Delta P = \frac{.00000336f \times 1 \times W^2}{.38 \times \epsilon}, \qquad \text{using } L = 1 \text{ ft. and } d^5 = .38$$

The values which have to be determined are: ϵ, W, f, ΔP.

ϵ from a table of properties of water for 170° F. = 60.8 #/cu. ft.

$$W = \#/\text{hr.} = 333\left(\frac{10{,}000}{30}\right).$$

f may be determined from Fig. 2 by solving for R:

$$R = \frac{6.32W}{d\mu} = \frac{6.32 \times 333}{.824\mu}$$

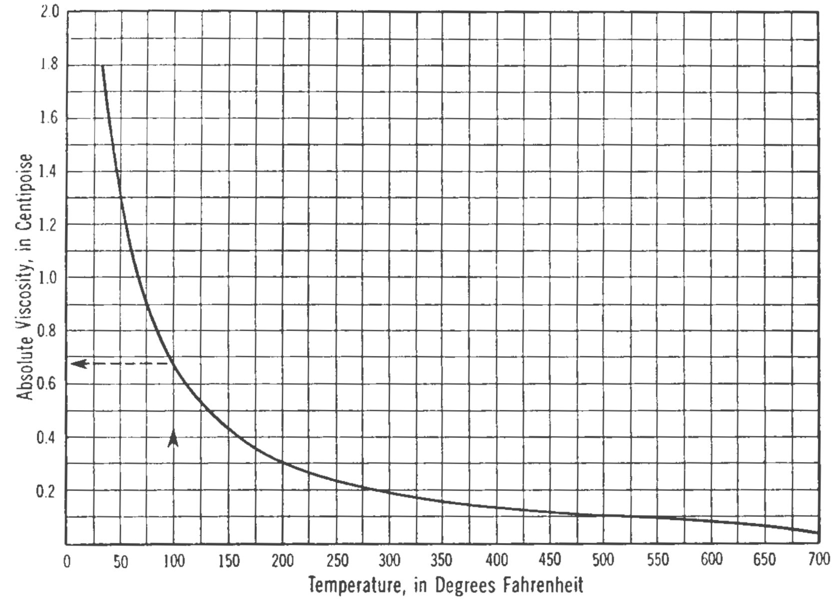

FIG. 3. ABSOLUTE VISCOSITY IN CENTIPOISES

where μ, the absolute viscosity in centipoises, may be obtained from Fig. 3 as 0.36 for 170° F. Then

$$R = \frac{6.32 \times 333}{.824 \times .36} = 7090.$$

It is interesting to note by referring back to Fig. 2 that, even at the low flow of 333 #/hr. or 0.68 gal./min., the flow is in the turbulent range and gives an f value of 0.038.

Substituting all of these values in the Fanning formula we have:

$$\Delta P = \frac{.00000336 \times .038 \times 1 \times 333^2}{.38 \times 60.8}$$

$$\Delta P = .000613 \ \#/\text{sq. in. per ft. of pipe,}$$

and as 27.7 in. of water = 1 #/sq. in.

$$\Delta P_1 = .01698 \text{ in. of water} = 16.98 \text{ milinches/ft.}$$

It is readily observed that the information given in Table 10 is quite accurate and, to a heating engineer who must calculate system friction heads, represents a major contribution.

In conclusion I would like to call attention to some of the major points given in the IBR Installation Guides.

1. Any hot water heating system of the gravity type requires precise design to produce the desired flow. The friction head must be sufficient to equal the differential head caused by temperature difference between inlet and outlet.

2. A forced circulation hot water system requires less accuracy in design than does a gravity system; however, accuracy will enable the designer to be more economical in the proper selection of pipe size and pump.

3. In a steam heating system of the gravity type the static head must be greater than the maximum friction head of the system.

4. A steam system should preferably be designed for low initial pressure and low pressure drop. If a system of this type designed for high initial pressure and a high pressure drop is operated at low pressure, it is likely to be noisy and have poor circulation.

Systems based upon IBR guides and authoritative handbooks provide for all of the above specifications automatically and eliminate much calculation. They permit design in a very convenient and orderly fashion.

III. FACTORS AFFECTING COMFORT

H. F. RANDOLPH*

The steam and hot water systems that have been discussed at this Short Course are not in reality heating systems at all.

Consider the kitchen refrigerator. Its purpose is to extract heat from the food stored therein in such a manner and quantity as to preserve the food. Likewise a steam or hot water system is used in a residence to help maintain an environment in which the human being loses heat at the same rate it is generated. Therefore, these systems are used to cool the body, not to heat it.

In your automobile engine, gasoline is burned to create power or energy for locomotion. In this process an excess of heat is developed which is carried off by the cooling system. Similarly, food is consumed by the body to create power or energy, and simultaneously an excess amount of heat is generated which must be dissipated by a cooling system. An engine that gets too hot burns out its bearings and stops. So with the human body that gets too hot and generates fever for too long a period; it stops — dead.

Surrounding the automobile engine is a jacket of water which picks up heat and carries it to the radiator, where the heat is transferred to the air and expelled.

As the body temperature rises, a thermostat automatically dilates the blood vessels in the skin, causing them to expand. Because the resistance to the flow of blood is decreased, more blood flows to the skin, which is the body's radiator. The skin temperature rises, giving off more heat and thereby cooling the body. Should this adjustment be inadequate, the sweat glands come into play, moistening the skin surface and adding the cooling effect of evaporation to radiation and convection.

Should the body temperature fall below the desired point the flow of blood is altered, a minimum going to the skin, which therefore cools and gives off less heat. If this adjustment does not restore the desired temperature, muscular activity is stimulated, such as shivering, stomping feet, or flinging arms to increase metabolism or heat generation.

The normal body temperature of a healthy adult is 98.6 deg. F. Increasing this only 1.4 deg. to 100 deg. F. brings the body to fever heat. When it is realized that our bodies often move from sub-zero temperatures outdoors to plus 70 deg. F. indoors in the space of

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seconds with little change in the amount of insulation in the form of clothing, it will be seen how responsive and effective the control mechanism of the human body actually is.

In maintaining an almost constant temperature of 98.6 deg. F. the body loses heat in several ways. Some heat is lost by expiration because the air inhaled is at a lower temperature than that exhaled. Some heat is lost by conduction to the floors, chairs, beds, and other objects in contact with the body. Some heat is lost by evaporation of moisture from the body surface. The majority of body heat loss, however, is by convection and radiation.

The body, being about 25 deg. F. warmer than the temperature of the indoor air in winter, gives off heat to the air. This is known as convection. Where two objects of different temperature face each other there is a net exchange of energy between them — a net loss by the warmer and a net gain by the cooler. This is known as radiation. So the human body, being warmer than the walls of its enclosure, loses heat to those walls by radiation.

Of the various means of body heat loss, convection and radiation comprise by far the largest amount, and these two are approximately equal in magnitude. Any system which in conjunction with the structure maintains the body heat loss at a rate that balances body heat gain and in a manner that is unconscious, will produce a comfortable environment.

In an uninsulated house in mild weather, comfort can be maintained with an air temperature of 70 deg. F. and a mean temperature of the walls and other surfaces of 70 deg. F. As the outdoor temperature drops, the inner surface temperature of the walls is depressed. This results in more heat being lost by radiation from the body to those walls, and a feeling of chilliness will result. To bring the body heat loss back into balance, less heat must be lost to the air by convection; so the house owner sets the thermostat higher to raise the air temperature. Again, as it gets still colder outdoors, the cycle repeats itself. It is because of the change in the mean surface temperatures of a house that one may be comfortable in 70-deg. air at some times and yet at other times require 76-deg. or 78-deg. air for equal comfort. Air temperature alone is not an index of comfort, and just because a heating system maintains an even temperature of say 72 deg. F. at some given location in a house it does not mean that comfort will result. A heating contractor having control of only a portion of the elements which affect comfort can not guarantee comfort. He can guarantee his equipment as capable of delivering a certain quantity of heat or he can guarantee it as adequate to maintain a predetermined air temperature — but not that that air temperature will be comfortable.

Obviously an ideal condition would be one in which both the air temperature and the mean surface temperature would be maintained at a predetermined value under all external conditions. This of course is an impossibility, but it does forcefully bring out the fact that the structure and the heating system can not be considered as independent of each other. Neither can produce comfort without the other, and furthermore a deficiency in one can rarely be corrected by changes in the other. Just as a crude example, a heating system can not be expected to overcome an objectionable draft from a poorly fitted window.

As has been shown, the temperature of the air enveloping the human body can be dropped as the surface temperature of the walls is raised, and vice versa, for equal body heat loss. It is relatively simple with any heating system to maintain a predetermined air temperature but it is far more difficult to maintain a predetermined surface temperature. As surfaces can be warmed much quicker by radiation than by convection it is desirable to introduce radiant heat, with the heat source so located as to raise the temperature of the coolest surfaces. That is one of the many reasons why correct radiator locations are so important.

The ability of air to absorb heat from the body is a function not only of temperature but also of velocity. At a given air temperature heat absorption will increase with velocity. While in summer this may be a desirable feature, it becomes objectionable in winter. Air movement that reaches the proportion of drafts may result from underheated second floors, causing the cool air to tumble down stair wells. It may also result from improper radiator locations which cause the air being cooled by the exposed walls to sweep across the floors.

The layman's first reaction to the question of insulation is generally the savings that can be made in the fuel bill. But of equal importance is the improvement in comfort that results. Because the heat transmission rate through an insulated wall is less, the inner surface temperature is higher, the body loses less heat to it by radiation and therefore must lose more heat to the air by convection. A lower air temperature is required.

This same condition applies to storm windows. The heat transfer through the glass decreases, the surface temperature of the inner pane of glass increases, the body loses less heat by radiation; so the air temperature again must be dropped to maintain balance. People often feel they are chilly when standing near a large expanse of glass because cold is flowing to them from the glass, whereas the opposite is true — heat is being drawn from the body by radiation.

In addition to the loss of heat by convection to the air and by radiation to the surfaces the third major means is by evaporation, the magnitude of which depends on the relative humidity. The drier the air the more moisture is absorbed from the body. Evaporation being a cooling process, higher air temperatures are required with low relative humidity for the same body heat loss. In modern construction, however, humidification is rarely a problem; rather, dehumidification may become serious.

There are only two reasons why artificial additions of moisture are required, infiltration and migration.

The outside air which infiltrates into a house through cracks around windows and doors is low in moisture content. As an example, zero air, even though saturated, will have a relative humidity of only 5 per cent when heated to 70 deg. F. if there is no moisture addition.

The number of grains of moisture per volume of indoor air is greater than that of outdoor winter air, so that the vapor pressure is higher indoors. Moisture therefore migrates through the walls, and, unless moisture additions are made, the indoor relative humidity will be reduced.

With modern construction it is quite customary to weatherstrip windows and doors, reducing infiltration to a minimum. Also when insulation is used in new construction a vapor seal is installed on the inner surface. This prevents moisture migration.

With such construction the normal domestic processes of washing, bathing, and cooking provide ample moisture — many times, so much that some means of dehumidification, such as a kitchen ventilating fan, must be provided. Therefore, while evaporation from the body, or relative humidity on which evaporation depends, is a comfort factor, it is not of serious proportions in modern construction.

And so it is important in designing and installing a heating system not only to provide adequate capacity to offset the heat loss of the structure but to so arrange the system as to maintain as uniform a temperature as possible of both the air and the surface. Bear always in mind the object: that you are not attempting to warm the human being but rather that you are attemping to create an environment in which the body can lose its excess heat unconsciously.

IV. TYPES, LOCATION, AND PERFORMANCE OF RADIATION

W. S. Harris*

The purpose of this paper is to present some of the ways in which radiator design and installation practices affect the over-all performance of steam and hot-water heating systems. It is important that designers and installers of heating equipment be well informed on this subject as, without question, improper selection or improper placement of radiation can be, and often is, the cause of unsatisfactory heating results. The material for this paper has been taken largely from two University of Illinois Engineering Experiment Station Bulletins: No. 223, "Investigation of Various Factors Affecting the Heating of Rooms with Direct Steam Radiators," and No. 358, "A Study of Radiant Baseboard Heating in the I=B=R Research Home." For a more complete discussion of the subject the reader is referred to these two bulletins.

Radiator Location

General Statement. — The location of the radiator in the room is very important, as it affects both the air temperature distribution and the air movement and can easily mean the difference between a satisfactory and an unsatisfactory job. At one time a study was made in the I=B=R Research Home in order to determine the effect of the location and arrangement of radiators on the comfort conditions maintained within a heated room. Tests were made in which five different locations and arrangements of radiators were used in the living room. In three of the installations, single radiators consisting of 24 sections of 19-in. 4-tube, small-tube type radiation were used. In the other two installations the same amount and type of radiation was divided into two 12-section radiators. When the radiator was changed to the inside wall in the living room, corresponding changes were made in the location of those in the dining room and kitchen in order to minimize differences between rooms. In addition to the routine temperature readings made with each radiator installation, smoke studies were made in the living room in order to determine the nature of the air movement.

Room Temperature Gradients. — Figure 1 shows the location and arrangement of the radiators used in each of the five installations

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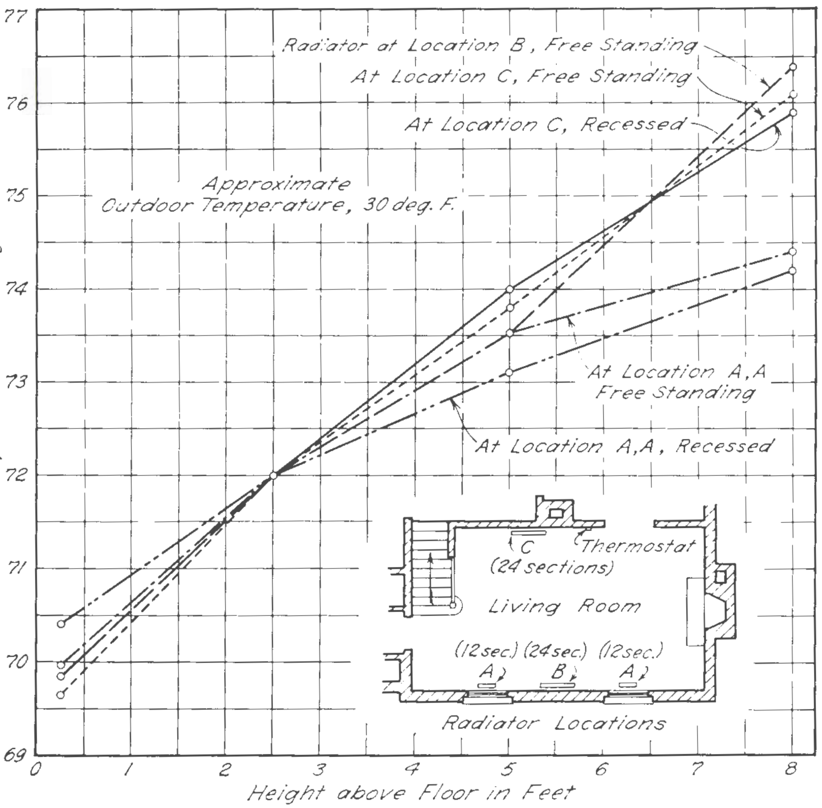


FIG. 1. AIR TEMPERATURE GRADIENT IN LIVING ROOM WITH FIVE DIFFERENT RADIATOR INSTALLATIONS

tested and the air temperature gradient obtained in the living room with each installation. The temperature gradients shown in Fig. 1 were obtained for days when the average outdoor temperature was approximately 30 deg. F. These curves are also characteristic of those obtained for colder weather, but in the latter case the gradients were steeper and the differences in the temperatures produced by the various installations were accentuated. At an outdoor temperature of 15 deg. F. the temperatures at the floor were approximately 1 deg. F. lower and the temperatures at the ceiling were from 1 to 1.5 deg. F. higher than those shown in Fig. 1. The curves in Fig. 1 indicate that with a given radiator location, similar temperature gradients were obtained within the room with both the free-standing and the recessed arrangements.

All five of the radiator installations produced approximately the same temperature gradient in the living zone, or that portion of the room below the 60-in. level. However, at the floor and at the 60-in. level slightly higher and lower temperatures, respectively, were obtained with the recessed radiators under the windows than were obtained with the other installations.

The lowest ceiling temperature, approximately 74.5 deg. F., resulted when the radiators were placed under the windows in position A. Slightly more than 76 deg. F. was obtained when they were located adjacent to the walls in positions B or C. Normally, high temperatures at the ceiling have little bearing upon the comfort of occupants, but they do result in higher heat losses from the structure, particularly in rooms having ceilings exposed to the outdoors or to unheated attic spaces.

Air Movement. — From the consideration of temperature gradients it would appear that just as good operating results may be obtained from a radiator located along an inside wall as were obtained from one located in any other position except under a window. However, since both dry-bulb temperature and air movement are factors influencing comfort conditions, the use of air temperature gradients alone as a basis for comparing the performance of different radiator installations in a given room may be misleading. Smoke studies, therefore, were made in the living room to determine the amount and direction of the air movement resulting from the use of each of the five radiator installations. Results are shown by the diagrams in Fig. 2. These diagrams show the locations in which high or critical air velocities occurred, and the numbers indicate the magnitudes of the velocities in feet per minute.

When the two radiators were located in the positions shown as A, Fig. 1, up currents of heated air from the radiators intercepted any down currents of cold air from the windows and thus prevented cold drafts across the floor. At the same time the cold air coming down over the windows mixed with the heated air rising from the radiators and thus lowered the temperature of the air traveling towards the ceiling. As a result the temperature of the air at the ceiling was moderated. Since even in very cold weather the temperature of the inside surface of exposed walls was only about 3 deg. F. lower than that of the air in the room, there was little flow of cold air down these walls and across the floor.

When the two small radiators, located under the windows at A, were replaced by a single radiator located between the windows at B,

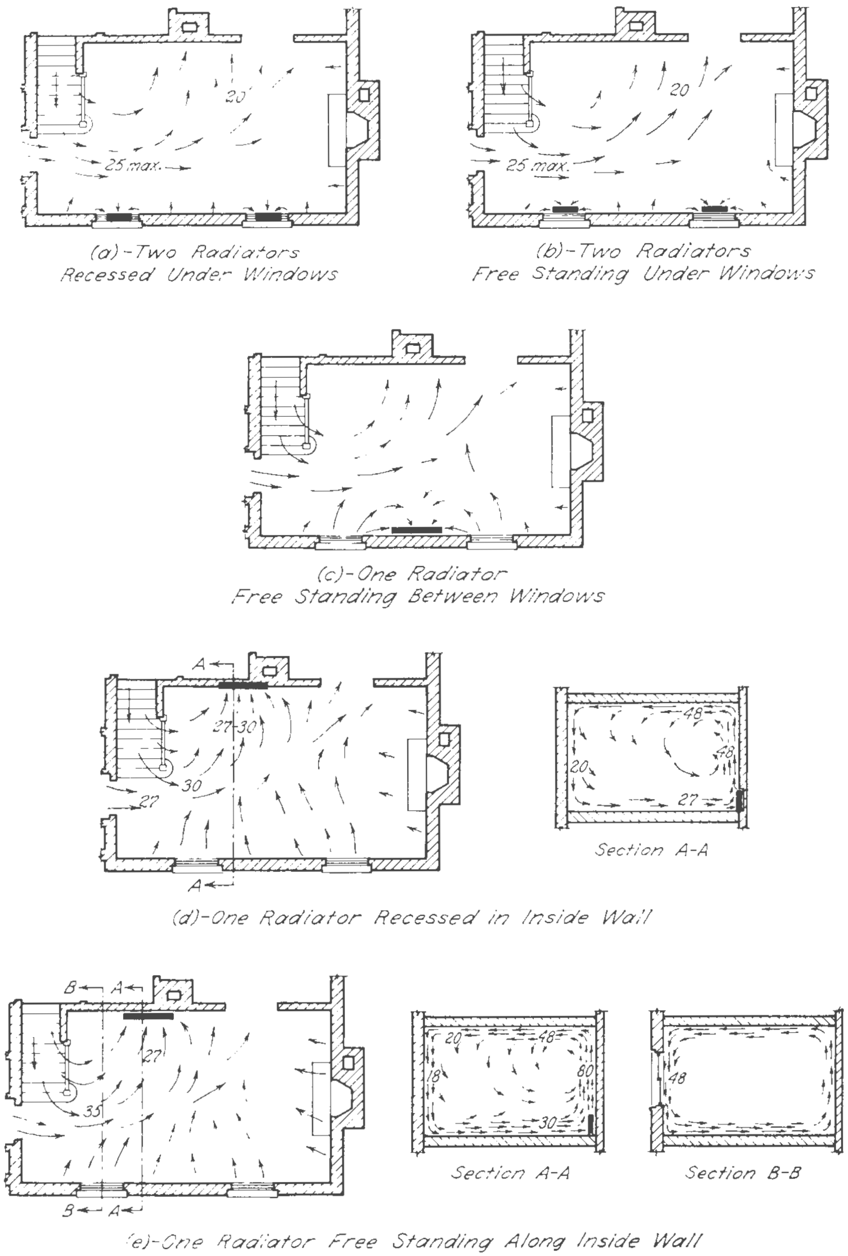


FIG. 2. AIR MOVEMENTS IN LIVING ROOM WITH FIVE DIFFERENT RADIATOR INSTALLATIONS

the air currents across the floor of the room remained practically the same except for a slight movement of cool air from the windows toward the center of the room. The greater part of the cool air from the windows, however, was drawn directly into the radiator. In the absence of a window or other cold surface above the radiator the heated air rose to the ceiling, resulting in comparatively high temperature, as shown in Fig. 1. It then settled uniformly throughout the room.

With radiators at either location A or B, along the exposed wall (Fig. 1), cool air from the vestibule and stairway entered the room and the main current moved in a large arc through the middle of the room toward the unexposed wall and archway between the living room and dining room. The maximum velocity was approximately 25 ft. per min. No objectionable drafts were observed at any time during the operation of the heating system with the radiators at either position.

A marked increase in the movement of air over the floor was observed as soon as the radiator was placed along the inside wall at position C. In this case the main air current originating in the vestibule and at the stairway was augmented by cold air from the windows and exposed walls. Air velocities across the floor as high as 35 ft. per min. were observed. Under these conditions, cold drafts were noticeable around the ankles, and the room was less comfortable than it was when the radiators were located along the exposed wall, in spite of the fact that the temperature of the air at the floor remained unchanged at 69 deg. F.

Increasing the velocity of air at 69 deg. F. from 20 ft. per min. to 35 ft. per min. lowers the effective temperature by approximately one-half degree. With a given air movement this is equivalent to lowering the dry-bulb temperature 1.5 deg. F., or from 69 deg. F. to 67.5 deg. F. Such a change is of sufficient magnitude to be distinctly noticeable, particularly when occurring near the lower limit of comfort.

RADIATOR ENCLOSURES AND SHIELDS

Tests have shown that the use of a properly designed enclosure or shield on a tubular or column radiator results in a gain in steam economy, and equally or more satisfactory air temperature conditions in the room as compared with those obtained by the use of the same radiator unenclosed. Apparently, however, there is little or nothing to be gained by the use of enclosures or shields on wall radiators. A properly designed enclosure or shield should offer a minimum of resistance to the flow of air over the radiator under gravity head, and should

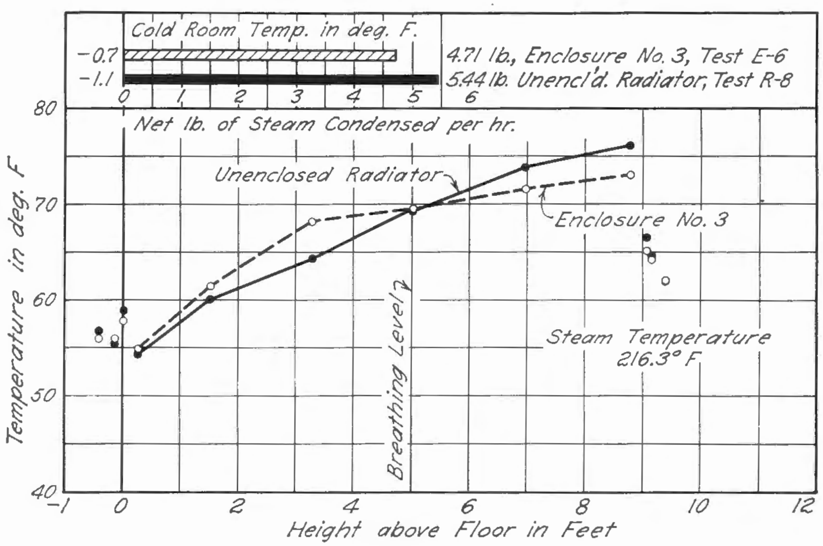


FIG. 3. ROOM TEMPERATURE GRADIENTS IN TESTS ON A TUBULAR RADIATOR, ENCLOSED AND UNENCLOSED

protect the wall behind the radiator against the effect of direct radiation from the radiator. It should have the top of the opening in the face of the enclosure as high as possible, and permit free access of air over the lower half of the radiator, especially near the floor.

Figure 3 shows the room temperature gradient obtained during tests made in the low-temperature testing plant located in the Mechanical Engineering Laboratory at the University of Illinois on an unenclosed tubular radiator, and on the same radiator when equipped with a properly designed enclosure. The low-temperature testing plant consists of a typical room of uninsulated frame construction, containing conventional windows and doors, which is located within a larger refrigerated space in which the temperature can be maintained at any desired value simulating winter outdoor temperatures. The temperature within the smaller room is maintained at normal room temperatures by means of the radiator being tested.

The use of the enclosure resulted in a higher temperature, and hence more comfortable conditions in the living zone, and in lower temperatures at the ceiling than those obtained with the unenclosed radiator. Furthermore, these results were obtained with less steam condensation in the case of the enclosed radiator. Thus the enclosure proved to be both effective and economical.

PAINT ON RADIATORS

The effect of various paints on the output of radiators has been studied by various investigators. The results of tests made by C. H. Fessenden and Axel Marin* are given in Table 1.

From data in this table it is evident that the use of oil paints gave practically the same results irrespective of color. In the case of solar radiation, color is an important factor, but in the case of the infrared radiation given off by the low-temperature radiators color is a secondary factor, and the amount of heat radiated is determined by the contour and the nature of the surface. In the case of the tubular radiator the oil paints gave practically the same heat transmission as the unpainted surfaces.

The metal bronze paints reduced the efficiency of heat transmission, the reduction ranging from 7.4 to 9.2 per cent. Thus the use of bronze paints is not to be recommended unless a corresponding increase is made in the size of the radiator. The use of bronze paints on radiators will not ordinarily affect the fuel consumption required to heat a given space.

TABLE 1

EFFECT OF PAINT ON OUTPUT OF TUBULAR RADIATORS

Radiator Finish	Relative Rating, per cent
Linseed oil, zinc, lithopone paint — Brown color	104.9
Linseed oil, zinc, lithopone paint — Cream color	104.0
White-gloss enamel	102.2
Bare iron, foundry finish	100.0
Aluminum bronze	93.7
Gold bronze	92.6

RADIATOR DESIGN

Tubular and Wall Radiators.—At one time tests were made in the low-temperature testing plant located in the Mechanical Engineering Laboratory at the University of Illinois to compare the operating characteristics of tubular and wall-type radiators. The results of these tests are shown graphically in Fig. 4. From Fig. 4 it is evident that when the tubular and the wall-type radiators were operated under practically identical conditions with 69.6 and 69.3 deg. F. at the breathing level in the test room, and temperatures of — 2.2 and — 2.9 deg. F. in the cold room, the temperature conditions in the room were much improved by the use of the wall radiator. When using the wall

* "Experiments on the Effect of Surface Paints on Radiator Performance," American Society of Heating and Ventilating Engineers Journal, Vol. 34, No. 12, Dec. 1928.

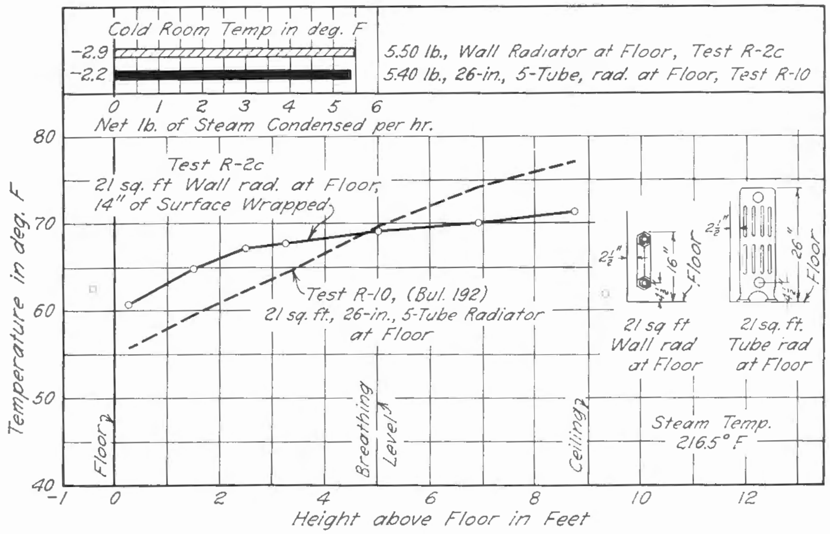


FIG. 4. OPERATING CHARACTERISTICS OF TUBULAR AND OF WALL-TYPE RADIATORS

radiator the temperature difference between the air at the floor and at the ceiling was only 10.8 deg. F., as compared with 21.4 deg. F. obtained with the tubular radiator. In addition the temperature of the air 3 in. above the floor was 60.8 deg. F. with the wall radiator and only 55.7 deg. F. with the tubular. Thus the whole "living zone," or zone below the breathing level, was much too cool for comfort in the case of the tubular radiator, while it was sufficiently warm for comfort in the case of the wall radiator. A fair criterion for this condition may be obtained by comparing the temperatures at the 30-in. level, since the temperature at this level is a reasonably close approximation of the average temperature in the whole zone below the breathing level. These temperatures were 67.3 and 62.2 deg. F., respectively, for the wall and the tubular radiators.

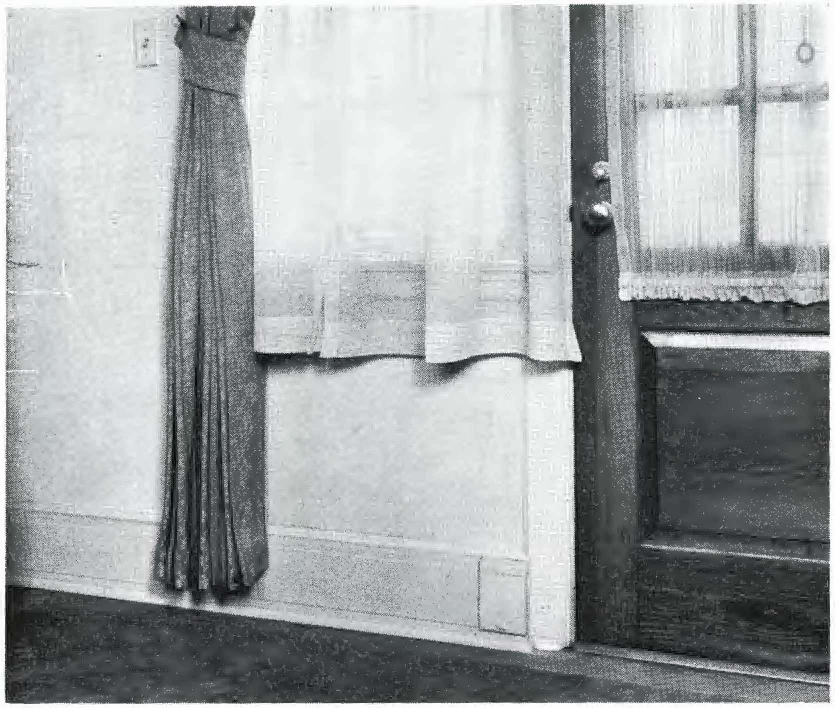
In addition to the tests in the low-temperature testing plant some corollary data were obtained from radiators installed in two second-story office rooms in the south wing of the Mechanical Engineering Laboratory. These two rooms had substantially the same amount of exposed wall and glass area, and both were exposed to the same outside conditions. One room, No. 212, was heated by a wall radiator located under the windows; the other, No. 214, was heated by a 38-in., 2-column radiator. The results of the tests in the office rooms were in general agreement with the results obtained in the low-temperature

testing plant, except that for the wall-type radiator in the office the floor-to-ceiling temperature difference was only 2 deg. F. instead of 10 deg. F. as obtained in the low-temperature testing plant.

From these results the following conclusion may be made. Long, low, thin cast-iron radiators placed under windows heat a room more comfortably and more economically than higher column or tubular radiators similarly placed, and they maintain materially better floor-to-ceiling temperature differentials than high column or tubular radiators.

Radiant Baseboard.—To take advantage of the better operating characteristics of long, low radiators and to improve the appearance in the room a unit has been developed which extends along practically all of the outside wall and does not interfere with furniture placement. This is the radiant baseboard, which seems to be destined to be very popular, both because of its excellent performance characteristics and because of its pleasing appearance in the room. A photograph of a typical installation is shown in Fig. 5. For several years the performance characteristics of radiant baseboard have been carefully observed in the I=B=R Research Home. The results of these observations were extremely gratifying.

As shown in Fig. 6, at an indoor-outdoor temperature difference of 70 deg. F., when the three bedrooms were heated by the radiant baseboards the average floor-to-ceiling temperature difference was only about 2 deg. F., as compared with 5½ deg. F. when the rooms were heated by conventional recessed radiators. An indoor-outdoor temperature difference of 70 deg. F. is approximately equal to an outdoor temperature of 0 deg. F. For the sake of clarity, only the temperatures 3 in. below the ceiling, at the 30-in. level, and 3 in. above the floor are shown. However, when the radiant baseboards were used, the temperature at the 60-in. level was the same as that 3 in. below the ceiling. Thus the entire temperature difference occurred within a zone extending from 3 in. above the floor to the 60-in. level. At an outdoor temperature of 0 deg. F., the temperature 3 in. above the floor was 71.1 deg. F., the temperature at the 30-in. level was 72.0 deg. F., and the temperatures 60 in. above the floor and 3 in. below the ceiling were each 72.9 deg. F., while the corresponding temperatures when using small-tube radiators were 69.7 deg. F., 72.0 deg. F., 73.3 deg. F., and 75.3 deg. F., respectively. Thus it may be observed that the use of radiant baseboards resulted in a temperature 3 in. above the floor 1.4 deg. F. warmer than that which is obtained with the conventional recessed radiators.



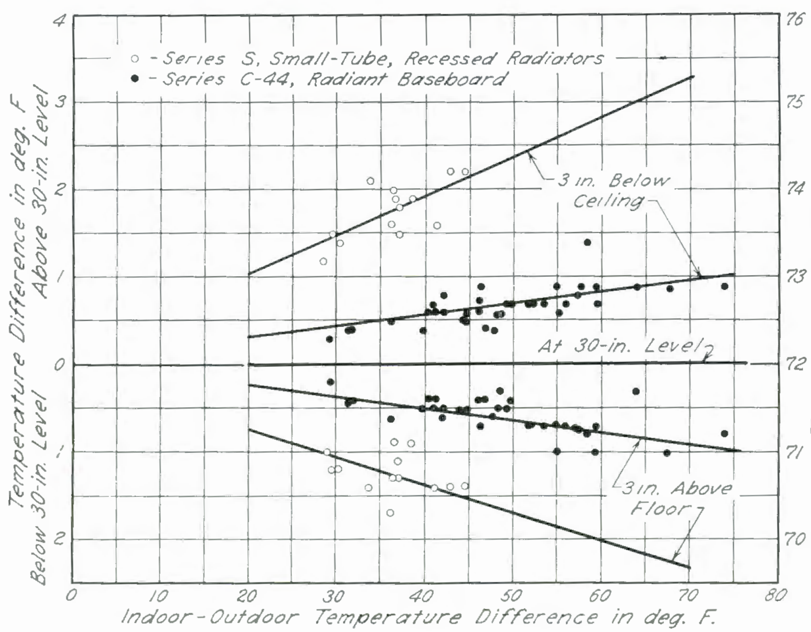


Fig. 5 (Above). Typical Installation of Radiant Baseboard

Fig. 6. Second-Story Air-Temperature Differentials

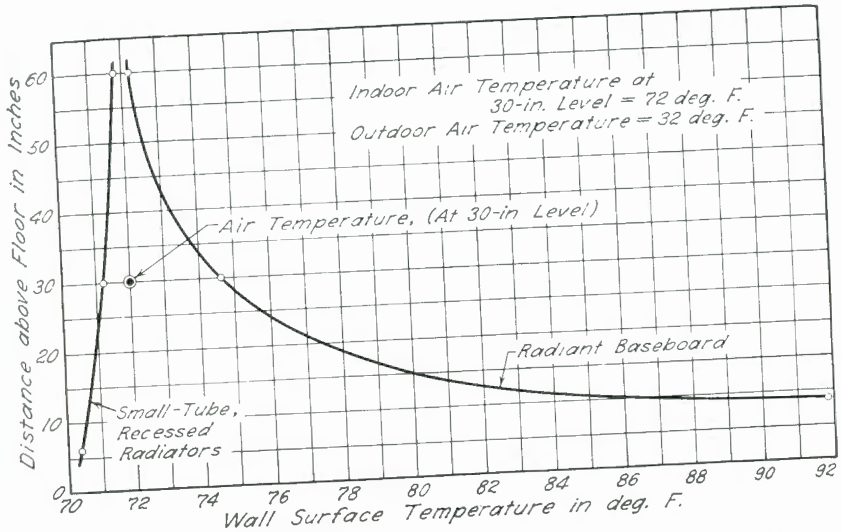


Fig. 7. Inside Surface Temperature of North Wall of Living Room

Even more striking evidence of the tendency of the radiant baseboard to produce warm air near the floor was presented in the case of the lavatory on the first story of the Research Home. The floor of this lavatory, which adjoined the unheated garage, was an extension of the concrete floor of the porch and was laid directly on the ground. Conditions in the lavatory were typical of those encountered in certain types of basementless houses. When using small-tube radiation in this room the temperature of the air 3 in. above the floor was approximately 64 deg. F. when the outdoor temperature was 0 deg. F., and the temperature of the room air 30 in. above the floor was 70 deg. F. For the same conditions of outdoor temperature and indoor temperature at the 30-in. level, the use of radiant baseboard in the lavatory resulted in an air temperature 3 in. above the floor of 69.7 deg. F., only 0.3 deg. F. lower than the air temperature at the 30-in. level.

A cold floor is a major contributor to discomfort in otherwise well-heated rooms; hence the tendency to produce a warm floor may be regarded as an important attribute of radiant baseboards. This attribute is most important in the case of the basementless house, in which cold floors are particularly prevalent. Therefore the use of radiant baseboards is especially adaptable to this type of construction.

Figure 7 shows the wall surface temperatures (measured on the inside surface of the plaster on the north wall of the living room) resulting from the use of the recessed small-tube radiators and the radiant baseboards. At the times that these observations were made, the outdoor temperature was approximately 32 deg. F. and the temperature of the air in the living room at the 30-in. level was 72 deg. F. It may be observed that with the radiant baseboard the temperature of the entire wall below the 60-in. level was greater than the temperature of the room air at the 30-in. level, whereas with the conventional recessed radiator the temperature of this portion of the wall surface was from 0.2 to 1.6 deg. F. below the temperature of the air at the 30-in. level. Thus, up to a height of 60 in. the radiant baseboard warmed the entire surface of the portion of the exposed wall along which it was installed. On the other hand, with the conventional recessed radiator, only the small portion of the wall forming the back of the recess was warmed; and this contributed nothing to comfort, because this portion of the wall was hidden by the radiator, which was at a much higher temperature.

If all other factors except the wall surface temperature remained unchanged, the increase in the wall surface temperatures accompanied by the use of the radiant baseboard would result in an increase in the mean radiant temperature in the room. However, measurements made at the 30-in. level by means of both a thermo-integrator and a globe thermometer in five different locations in the living room proved that with conventional recessed radiators the mean radiant temperature was about 1 deg. F. higher than the air temperature and that with the radiant baseboards the mean radiant temperature was from 0.5 to 1.0 deg. F. lower than the air temperature. This condition is just the reverse of that to be expected from the wall surface temperatures obtained. The higher mean radiant temperature obtained with the conventional recessed radiators must have been the result of the higher ceiling temperatures accompanying the use of these radiators. These mean radiant temperature observations indicate that, in an insulated house, even though the use of radiant baseboards results in warmer air near the floor and in warmer inside surfaces for the exposed wall, in order to produce the same degree of comfort it would still be necessary to maintain the same air temperature at the 30-in. level with the radiant baseboards as would be required with the conventional recessed radiators. Hence the main advantage of the radiant baseboard lies in the fact that the use of this type of radiation insures that warm floors will be obtained.

The tests made on the radiant baseboard also showed that these units were very clean in operation, they reduced streaking of walls to a minimum, and curtains at windows over the radiant baseboard remained as clean as similar curtains at windows under which no radiators were located. Furthermore, there was no increase in the seasonal cost of operation as compared to the cost of operation when using the small-tube radiators.

Summary

The contents of this paper may be briefly summarized as follows:

For most satisfactory operation radiators should be located adjacent to the points of highest heat loss from the room — that is, along exposed walls and preferably under windows. In general, a long, low, thin radiator has better performance characteristics than a thicker, shorter, and higher radiator.

The use of a properly designed enclosure or shield on a tubular or column type of radiator results in a gain in steam economy, and equally or more satisfactory air temperature conditions in the room as compared to those obtained with the same radiator unenclosed.

Painting a radiator or enclosure with an oil paint, irrespective of the color of the paint, has no material effect on the heat transmission as compared with that for foundry finish or oxidized iron. However, the use of bronze paints on tubular radiators reduces the heat output rates by approximately 7 to 9 per cent.

V. A TRADE ASSOCIATION AT WORK

R. E. Ferry*

There is a story of a superintendent of a hospital for mental patients who was taking an acquaintance on a tour of inspection of the buildings and grounds. Coming upon a group of patients who, without any supervision, were congregated in animated discussion, the visitor remarked, "Aren't you afraid that these people will get together on a plan for making trouble or for making a mass exodus?" The superintendent replied, "Lunatics do not collaborate."

By inverse analogy, that story points to the raison d'être — the reason for being — of trade associations. I do not intend to convey the inference that all men or corporations are lunatics who, for reasons of their own, do not belong to an association of their particular industry. The significance of the analogy is that no one company is as big as the industry of which it is a part. There are problems confronting every industry, the solution of which is too broad to be attained by individual action or effort. Collaboration on the part of a group of companies within an industry can accomplish things which no one member can accomplish. The progressiveness of an industry can usually be gauged by the strength of its trade organization.

Of course, someone might interrupt at this point to offset my story of the superintendent of the mental institution by relating another of a visitor to a similar institution who said, "Do you have to keep the women inmates separated from the men?" The reply was, "Sure! The people here are not as crazy as you think." However, I hope I can prove my point that the history of trade associations demonstrates that collaboration by a group of competitors within an industry can accomplish certain aims which benefit its members, its customers and the final arbiter — the consuming public.

A trade association, as defined by the United States Department of Commerce, is a voluntary, non-profit organization of business competitors, the objective of which is to assist its members and its industry in dealing with mutual business problems in several of the following areas: accounting practices, business ethics, commercial research, industrial research, standardization, statistics, trade promotion, and relations with the Government, with labor, and with the general public.

The regular members of I=B=R are the manufacturers of cast iron boilers and radiators. We also have international members who are Canadian manufacturers of these products. Associate membership

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is open to manufacturers of equipment which is used with hot water and steam systems — water heaters, controls, valves, and like products.

Unfortunately, the history of trade organizations is not free of blemishes. There have been sufficient evidences of the abuse of power by cooperative action on the part of trade associations to raise questions as to whether the objectives of a given group are constructive or destructive. Promoting a common cause can be destructive if the actions of a group have the effect of restraining trade.

In the early period of development of trade associations — i.e., between 1853 and 1898 — primary emphasis was put on restricting competition by means of price agreements, arbitrary and uneconomic basing points, allocation of customers, agreements to sell or refrain from selling to certain customers, and various other devices that were designed to put the non-cooperative producer out of business. Such unsound measures resulted in legislation such as the Sherman and Clayton Acts, the essence of which is that two or more competitors shall not agree to anything which restrains normal trade and restricts normal competition.

These abuses of power, derived from destructive cooperative action, are mentioned for the purpose of highlighting, by contrast, the benefits available to an industry and its customers from constructive achievements designed to promote a common industry cause.

Before I present to you a review of what constitutes a trade association at work, as exemplified by I=B=R, it may be of interest to trace briefly some of the early history of the steam and hot water heating industry. Everyone in this audience is interested in that industry and, therefore, is interested in its antecedents.

The problem of providing comfort through heat is in no way changed from what it was at any time in the past. Stripped to its essentials, the science of heating involves the transfer of heat from its source — i.e., a fire — to the location where the human body happens to be. There has been, since the beginning of time, no change in the intensity or value of heat in a flame; the only change involved, therefore, is the development of more adequate means for the transfer of heat. The supplying of heat is thus a problem of transportation rather than of production.

If we trace the evolution of the transportation of heat for comfort purposes, we start with the cave man striking fire with a flint, igniting whatever dry underbrush happened to be nearby, and transporting the burning embers to form the first hearth fire in his cave. At a much later date the difficulties of striking fire led to the public office of

"Keeper of the Fire," whose job it was to constantly maintain a flame from which private fires could be made.

Coming on down through the centuries, we find records of the Greek prytaneum — the official hearth of the city — from which the fires of outlying colonies were kindled — a symbol of hospitality and a sacred bond between the mother city and the colony. Further advancement in the science of heating was found some years ago in the ruins of an excavated Greek palace on the island of Cyprus where a room was discovered to which water was conducted in three conduits and then boiled in order to supply steam heat for bedrooms on the second floor.

Later the Romans added to the art of supplying comfort through the medium of heat by building hypocausts under their baths and later under their houses. Thus the basement was originated as the location for heating equipment. Fed by logs, the hypocaust delivered heat through openings connected to hollow bricks, along the floor and up the side walls. Coming on further through history, we find the hearth fire in England, progressing from the stage of covered pyramids to carry the smoke through the roof, to the forerunner of the modern chimney, which meant the moving of the fire from the center of the room to the side wall.

Probably the earliest installation of a modern heating system of which there is a record is in the 18th century in France, when Bonnemain constructed a hot water heating system in an incubator. Nineteenth century publications include a book by Tredgold, published in England in 1824, "Principles of Warming and Ventilating Public Buildings," and one by Hood, entitled "Treatise on Warming Buildings with Hot Water, Steam and Hot Air," published in 1837.

The fathers of the central heating system as we know it now were the Nobel brothers (Alfred, Robert, and another brother), who left Sweden and set up a manufacturing business in Russia prior to the Civil War (about 1850); this was before the advent of the Mills boiler in this country, which was, I believe, the first sectional cast iron boiler. The Nobel brothers, who established in Russia a pump and steam engine manufacturing business, took a contract from the Czar to heat his palace with a forced hot water central heating system. This system, including the radiators, was constructed from pipe made by the Nobel brothers, who held a number of patents covering the design, manufacture, and installation of a central heating plant.

Early radiation, as used by Nobel, consisted of pipes; later on, the pipes were clustered in what is now known as a radiator. The sectional cast iron radiator made its appearance early in this century and

was based on the revolutionary Safford patent. A number of companies produced radiators based on this patent. The first radiators were very ornamental, in keeping with the spirit of the times — the Gay '90s — and represented a work of art which was a credit to the pattern-making trade. With the passing of this era, the floral and rococo features were removed and the simple, plain, large column sections moved in.

About the middle '20s, a tubular-type radiator made its appearance and, practically overnight, the column-type radiators were replaced. This development first started in Europe under the Louis Corto patent and was quickly picked up in this country.

Within the last 12 years the simple, small-tube radiator has appeared. Radiator design has invariably followed the trend of the times. Slim-tube radiation lends itself to architectural simplicity, and its installation is in keeping with modern lines. Of greatest importance is the fact that the radiator has been subdued in appearance but enhanced in efficiency.

No description of recent developments in radiation is complete without reference to convectors and convector-radiators. The forerunner of the present convector was the Gold Pin radiator. In its original application it was installed in the floor with two large inlet and outlet openings. The cold air under the floor became heated by the large amount of indirect surface contained in the radiator and rose into the room at the other end through the outlet grille. You can readily see the unsanitary condition that prevails in a unit so installed.

Another unit of similar type, having a large amount of secondary surface, was introduced. The secondary surface was composed of random spiral turnings, such as are obtained when turning a bar of metal on a lathe. These spirals were soldered to the prime surface of pipe, thereby giving the pipe additional radiating and convecting surface.

About 1930 the non-ferrous, hot cabinet or free standing convector made its first appearance. This originally consisted of a heating element composed of one or more copper tubes, over which copper fins were either pressed or soldered to form the extended secondary heating surface. This type of convector has continued its evolutionary development since that time. Other metals besides copper have been employed, such as aluminum and steel.

The demand for concealed radiation was met by the cast iron industry with the introduction of cast iron convectors. This form of radiation has seen many changes; today it is characterized as a heating unit of cast iron, containing integral cast fins, with a proper distribution of secondary to prime surface. These convectors are installed in enclosures or concealed in the wall. One might say that the present convector is the resurrection of the old Gold Pin radiator, except that a more sanitary way of installation is now employed.

Baseboard types of radiation are the most recent development in the field of radiant heating, and all indications point to their being an important factor in the future.

In addition to small-tube radiators, baseboards, and convectors, the benefits of radiant heating are available with panels — floor, wall, or ceiling.

These brief references to the evolution of hot water and steam systems may be summarized by saying that present-day modern systems present a choice of four heat transmission media: radiators, convectors, baseboards, and panels, from any of which comfort may be obtained because —

1. The straight line movement of radiant heat rays warms all surfaces of the room without creating drafts and without the need of high air temperatures.
2. There are no cold areas at the windows and along outer walls — all sections of the room are made comfortable by the correct placement of heating units.
3. When the source of heat is shut off there is a gradual slowdown in the transmitted heat, rather than an abrupt stoppage.
4. Temperature differences from floor to ceiling are slight.
5. Radiant heat is clean heat.
6. In the radiant heated home, rooms exposed to germs or bacteria (sick rooms) may be closed off so that infection is not spread by the heating system.

You may ask what does all this have to do with the work of a trade association — i.e., I=B=R. There is a very direct relationship, because the evolution of these modern systems and the evaluation in specific terms of what these systems will produce in the way of comfort stem directly from the activities of the Institute. The principal aims to which the I=B=R program has been devoted in recent years are:

1. Testing and Rating of equipment — boilers, radiators, convectors, baseboards, and water heaters.
2. Research investigations for studying the efficiency of heating plants under actual operating conditions and the effect of various systems of heating on environment and comfort.
3. The translation of these research investigations into a series of installation guides.
4. The stimulation of consumer demand for hot water and steam systems — in other words, an advertising and publicity campaign.

These four major I=B=R Projects affect the business of every heating wholesaler and contractor. The balance of my remarks, therefore, will be devoted to a brief outline of the manner in which these problems have been and are being attacked and how you can profit by the work being done. The description of these four major projects does not constitute, by any means, a complete picture of all of the Institute's activities. The broad scope of the I=B=R program is attested by the fact that there are 23 different committees actively working on the various phases of the Institute program. It is appropriate to emphasize the fact that the constructive work being done by the Institute can be attributed to the fact that the members of these various committees give freely of their time and ability to accomplish the objectives of the Institute for the good of the entire industry.

Boiler Rating Program

Thirty-two years ago, in 1915, the manufacturers of cast iron boilers and radiators formed an association which later became known as The Institute of Boiler and Radiator Manufacturers. The minutes of their meetings show that, from the start, the need for a scientific method for determining the output of boilers was recognized as of primary importance. However, it was not until 1939 that the manufacturers reached a point where they could say to their customers, "The published performance of our boilers is based on actual output as measured by a method devised jointly and cooperatively by the best engineering brains in the industry." That year, 1939, marked the birth of the I=B=R Testing and Rating Code for Low Pressure Cast Iron Heating Boilers. Prior to its adoption, boiler ratings were not based on any recognized standard; hence they were subject to question and were not universally accepted with confidence.

The I=B=R Testing and Rating Code is the detailed procedure to be followed by testing laboratories in order to determine the B.t.u. output of a boiler. It also prescribes the methods for determining the square feet of installed radiation which a boiler will conservatively take care of — in other words, the proper rating of a boiler as installed under normal field conditions.

I=B=R Ratings are expressed in terms of:

(a) "Gross I=B=R Output," which is the total quantity of B.t.u.'s which the boiler will deliver per hour and at the same time meet all of the limitations set forth in the Code.

(b) "Net I=B=R Rating," which is the amount of installed radiation which will be served by the boiler after making due allowance for piping and pickup.

The chimney cataloged for a tested boiler must be not less in height than the height for which the draft was regulated in determining the rating of the boiler. The Code specifies the maximum height and minimum area of chimney for each size of boiler.

I=B=R burner capacity is the hourly input rate required to develop the Gross I=B=R Output, expressed in gallons of oil or pounds of coal. I=B=R burner capacities must be shown on the nameplate of the boiler. The underlying purpose of this requirement is to insure the installation of an oil burner or stoker of sufficient capacity to develop the rating of the boiler.

Some of the requirements that must be met by the testing procedure before a boiler can bear the I=B=R emblem are:

Efficiency. The over-all efficiency of a boiler must be not less than that specified in the Code. These requirements have served to improve the performance of boilers since the establishment of the I=B=R Code.

Time Available Fuel Will Last. A hand-fired boiler must be able to maintain its Gross I=B=R Output for a specified length of time. This is to assure the ultimate user reasonably long firing periods and freedom from frequent attention intervals.

Carbon Dioxide (CO_2) in the Flue Gas. During oil-fired tests, the oil burner must be set to produce 10 per cent CO_2 in the flue gas. This requirement is established so that all boilers are rated on a comparable basis and to prevent anyone from obtaining ratings that are too high by testing his boiler with an exceptional oil burner under ideal conditions at a combustion efficiency which could not be reproduced in the field.

Flue Gas Temperature. The flue gas temperature at the Gross I=B=R Output of the boiler must not exceed 600 deg. F. during an oil-fired test. This insures the user of economical operation and of freedom from fire hazard. This temperature is measured in a thoroughly insulated stack; therefore in the ordinary field installation the stack temperature would measure only about 500 deg. F.

Draft Loss Through Boiler (Oil-fired). The draft loss through the boiler or the difference between the draft in the stack and the draft in the combustion chamber must not exceed a specified value. This requirement is included because excessive draft losses invariably lead to trouble when boilers are connected to poor chimneys or in poor draft areas.

Heat Release (Oil-fired Boilers). The heat input per cubic foot of net firebox volume must not exceed 80,000 B.t.u. per hour. This requirement insures ample combustion space in a boiler to provide reasonable freedom from pulsations and otherwise unsatisfactory burner operation.

The Boiler Technical Committee of the Institute continues to make constant studies of the testing procedure as covered by the Code. Eight years of experience in the various laboratories where boilers have been tested have proven that the Code was basically sound from its inception as applied to coal and oil-fired boilers. Work is now under way to expand the Code to provide testing procedure for gas-fired conversion boilers.

Before a manufacturer may publish I=B=R Ratings and use the I=B=R emblem, he must submit his complete test data to the Boiler Rating Committee of the Institute for approval. This committee consists of a representative body of highly qualified engineers. The purpose of their review is to determine whether the tests have been accurately performed and whether the ratings requested by the manufacturer conform to all of the requirements of the Code.

The value of the boiler testing program and its general acceptance by Government agencies, contractors, and engineers have stimulated I=B=R members to accomplish similar tasks covering hot water supply boilers, baseboards, convectors, and water heaters. The over-all objectives are the same — i.e., to place the manufacturers of these products in a position where evaluation of performance is based on scientific testing procedure.

This summary of Institute activities affecting equipment is not complete without referring to what has been done to simplify radiator sizes. Ten years ago there were more than 50 sizes of tubular radiation. Today there are nine sizes, which adequately meet the requirements of any type of structure. A similar program has just been completed for cast iron and non-ferrous convectors. Before the war, convector catalogs covered literally hundreds of thousands of convector combinations. The convector simplification program, jointly sponsored by the manufacturers and the National Bureau of Standards, will provide for less than 300 sizes and types.

Research

Mr. Kettering of General Motors is credited with saying, "Research is to keep you reasonably dissatisfied with what you have." A different, but wholly consistent, appraisal of the value of research was expressed by Professor Emeritus Kratz of the University of Illinois. At one of our early meetings he said that, in addition to the fundamental knowledge derived from research, there are certain collateral results, such as the fact that research by an industry impresses the public that it is making an honest effort to do something constructive. He went on to say that it is evidence to the industry's dealers that it is trying to help them to solve their problems, and thus research is a unifying tie between the manufacturers and their customers.

Your interest in the I=B=R Research program is only academic unless it produces results which help you to install more efficient systems, systems which satisfy your customers from the standpoint of maximum comfort and minimum cost of installation and operation.

In starting our research activities in 1940 a broad, long-range set of objectives was adopted. Those objectives were to find out conclusively how to install the most effective and economical hot water and steam systems, to determine the types and locations of equipment which will result in the greatest degree of heating comfort, to investigate questions of cost and economies of operation, and — of greatest importance — to meet the challenge of the small residential market.

The University of Illinois, with its background of some thirty years in experimental and teaching work in the heating and ventilating field, was selected as the medium for carrying out this work because the University had in its Department of Mechanical Engineering a research staff which knew our problems.

The I=B=R Research Home and the University's laboratories have provided the tools to carry out a wide range of scientific and yet practical investigations. To these there has been added this year a prefabricated house built on a concrete slab.

Time does not permit a listing here of all of the knowledge which has been derived from the I=B=R Research program. These facts are covered in numerous University bulletins which have been published and in a series of I=B=R Research Digests. As a pertinent example, and one which is of practical value to everyone who sells and installs hot water and steam systems, the actual cost of supplying domestic hot water has been determined where an oil-fired boiler was used with an indirect heater connected to a 30-gallon storage tank and where 50 gallons of 150-deg. water were supplied. The daily oil consumption was one-third of a gallon in winter operation and 1.4 gallons per day in summer operation. At 8¢ per gallon, the yearly cost was $20.40, or $1.70 per month. Omitting insulation from the piping between heater and tank increases the fuel consumption 20 per cent.

On the subject of radiator recesses, it was found that with uninsulated recesses seasonal fuel consumption increased 5 to 6 per cent and that 7 to 8 per cent more radiation is needed.

On the subject of humidity, it has been proven that indoor humidities adequate for comfort are maintained without the assistance of a humidifier where a tightly constructed house is equipped with a vapor barrier on all exposed walls and ceilings. Where normal family living activities are conducted, such as washing and cooking, relative humidity of approximately 30 per cent was found with an outdoor temperature of zero F.

These three examples are cited of the constant stream of fundamental knowledge which adds to the know-how of good heating and home construction. Many of the innovations in hot water and steam heating systems made in recent years are due to the I=B=R Research program or were thoroughly studied and tested in the Research Home. One outstanding example is Radiant Baseboards, which will, in my opinion, be an important factor in future installations. A second major outgrowth of the I=B=R Research program is the publication of the I=B=R Installation Guides which form the backbone of this Short Course. Several years of investigation proved the adequacy of the smaller pipe sizes and minimum amount of radiation which are called for in the Installation Guides. The research work at Urbana made it possible to state, without any doubts, that boiler sizes need not be larger to provide for domestic hot water unless the house contains more than two bathrooms or the daily consumption is over 75 gallons.

One interesting aspect of our research program this winter will be to prove a fact which is generally believed to be true, that a prefabricated house built on a concrete slab can be kept comfortable when heated with baseboards.

You probably have a question in mind as to what we are doing to find out more about panel heating. Who is going to resolve some of the presently published contradictions of B.t.u. output per square foot per hour? What are the correct design data for panels with varying types of construction? What about heating and cooling rates? What about controls, water temperatures, relative merits of wall, floor and ceiling panels, etc., etc.?

Frankly, we realize the importance of finding the answers to all of these questions, but we also realize the enormousness of the task. We are not shying away from it but we are not going to try to do it alone. The I=B=R group, in common with several other groups, is assisting ASHVE in carrying out an intensive research program on panel systems. The work has been started by a committee of engineers representing all elements of the heating and construction industries.

The ASHVE panel heating research program comprises four principal divisions:

A. Heat distribution, covering subjects such as the types, size and spacing of conductors, the various properties of material composing the panel, water temperatures, insulation, etc.

B. Heat transfer, including surface temperatures, absorptivity, position of the panel, etc.

C. Comfort conditions.

D. Controls.

I=B=R Installation Guides

The Installation Guide program has been mentioned as the third of four major projects in the current I=B=R program. In view of the fact that these Guides are being discussed in detail in connection with this Short Course, it is redundant for me to discuss at this time the contents of the Guides. I would like to clarify in your minds the over-all purpose for which these Guides were developed and to stress the importance which we attach to them as a means for broadening the market for hot water and steam systems in small residences.

These Guides are not intended to usurp the function of the engineer or heating contractor. They are a direct outgrowth of the I=B=R Research program which has been conducted at the University of Illinois over a seven-year period. As a result of that research work, we have developed accurate information on which to base installation details which require minimum pipe sizes, which means minimum installation costs. Coupled with that, the Guides provide simple methods of calculating heat losses for any type of small residence. If hot water and steam heating systems are going to compete successfully with other forms of heating, the price must be kept down and still maintain maximum comfort. Rule-of-thumb methods for determining heat losses, pipe sizes, and amount of radiation usually result in overloading the job. Frequently this means that the owner will specify a cheaper type of system or will obtain a lower price from a contractor who uses a scientific method of calculation.

Nearly 250,000 copies of the Guides have been distributed during the past three years. In the near future we hope to have Guide No. 5, covering Baseboard Installations. We expect also to enlarge the scope of Guide No. 1 so that complete details for a one-pipe forced hot water system for buildings with heat loss up to 150,000 B.t.u. will be available. A further step in this installation procedure will be to produce wall charts illustrating the general arrangement of boiler, radiation, and piping for the various types of systems. These will show enlarged details of special connections and will include tables of recommended pipe sizes, etc.

As I said before, this information which deals with installation procedures is not intended to move into the sphere of activities of the engineer and the contractor. It does translate into practical terms the results which have come out of years of intensive research. It helps, we believe, to place the installer of these systems in a better competitive position and thus broaden the future market for all of us.

Credit is due to the warm air manufacturers in their field training activities. They are helping their dealers to install better jobs by conducting classes throughout the country. The I=B=R group is now developing plans along similar lines. We hope, in the near future, to conduct nation-wide classes which will be miniature short courses. In this way we can reach thousands of installers each year and provide a two-day program devoted to the problems involved in calculating and designing hot water and steam systems.

Stimulation of Consumer Demand

The fourth and last major project of the I=B=R program is probably of greatest import to you. It is of no avail to learn more about the engineering aspects of our industry unless that knowledge can be translated into profits, and profits can accrue to the manufacturer, wholesaler, and dealer only as a result of consumer demand.

Immediately after the war, I=B=R made a survey among builders and architects to determine two things: first, what kind of heating systems would be in demand in postwar residential building; and, second, to what extent the consumer influences the decision. From that survey we arrived at two convictions. One, that if installation costs for our systems are not too high compared to warm air, a large percentage of builders and architects would like to use them; and, second, consumer demand does influence, to a large extent, the decision as to type of heating system.

For the first time in the history of this industry, a joint effort is being made by a group of manufacturers on a national scale to influence consumer demand through a strong and vigorous campaign describing the comfort benefits from radiant heating by means of radiators, baseboards, panels, or convectors. It must be admitted that in the past contractors have been left too much to their own devices in promoting these types of systems without concerted effort on the part of manufacturers. Now the manufacturers are stepping out to take the lead.

The Institute of Boiler and Radiator Manufacturers has embarked on an advertising and publicity program of considerable scope and long range. The important tool in that program is a consumer booklet designed to give, in layman's language, the advantages of hot water and steam systems.

The manufacturers comprising I=B=R membership are convinced that the trend toward warm air installations which developed during the ten years immediately preceding the war is being reversed in favor of hot water installations and can be accelerated through a sustained and well-planned promotional campaign.

Much is being said and written these days about "radiant heat." Many people believe that the terms "radiant heat" and "panel heat" are synonymous. They are not! Panel heat is only one method of obtaining the benefits of radiant heat. You who install hot water heating systems have much to gain by exploiting the virtues of radiant heating, whether you use radiators, baseboards, panels, or convectors.

The I=B=R consumer booklet, "ENJOY BETTER LIVING WITH RADIANT SUNNY WARMTH," features these four types of heat transmission, as providing the comfort obtainable from radiant rays. Among the potent sales arguments to which the book refers are:

Freedom from drafts
Cleanliness
Low repair and maintenance costs
Economical operation
Safety
Flexibility in cold or mild weather
Warm floors and small temperature gradients
Comfort throughout the room regardless of windows and outside walls
Year-'round hot water without a separate installation or burner.

The book urges the consumer to use the knowledge and skill of heating and piping contractors who assume the responsibility for proper installation.

I=B=R advertisements in consumer publications are designed to tell the public that copies may be obtained without cost from the Institute. In addition, the manufacturers purchase a supply at cost for use by their salesmen as a selling tool in their consumer contacts.

The members of the Institute are of the firm conviction that you can derive benefit in the same way by using this literature to help sell the virtues of hot water or steam systems to your customers.

Advertising campaigns sponsored by an individual manufacturer are designed to increase the demand for his particular brand of product. The I=B=R campaign has a vastly broader objective. It is designed to tell the consumer what constitutes good heating and how it may be obtained. The combined resources and engineering skill of twenty-four manufacturers have been merged into the pages of the I=B=R booklet, "ENJOY BETTER LIVING WITH RADIANT SUNNY WARMTH." Its contents are constructive — not controversial. It is an authoritative booklet, presented in a colorful manner, answering questions in a way which the layman can understand.

The Institute's members hope that it will be widely used by your companies and that you will see that it is placed in the hands of your salesmen. It can be a valuable asset as a selling tool in obtaining more hot water and steam heating installations in residential work.

The I=B=R advertising campaign is designed to accelerate a demand on which all of us in the industry will capitalize two, three, and five years from now.

If I may close on a personal note, may I say that a trade association executive whose industry is using its association to carry out a program of the nature such as I have just described may well feel that his job is worth while. Of course, that kind of job should require some of the characteristics that have been described as necessary for a successful insurance salesman. He should have: "The curiosity of a cat; the tenacity of a bulldog; the brashness of a Charlie McCarthy; the determination of a cab driver; the diplomacy of a wayward husband; the patience of a self-sacrificing wife; the deductive powers of a Sherlock Holmes; the persuasiveness of a politician; the enthusiasm of a radio announcer; the good humor of an idiot; the self-assurance of a college graduate; and the tireless persistence of a bill collector."

May I impress on you the fact that the members of I=B=R recognize, as never before, the responsibility to their customers and to the public to maintain high standards in conducting the business of their industry so that there will be engendered a confidence in their products and that they will command the respect of all with whom they have business relations.

This Short Course in which you have been engaged is an outstanding example of the type of opportunity which the Institute desires to provide so that you and others in the same line of business may obtain first-hand information on hot water and steam heating systems. I sincerely hope that you have found the course informative and wholly worth while and that you have derived therefrom a considerable degree of inspiration to enable you to compete vigorously for your share of the heating business in your particular localities. If that result has been accomplished, the University and the Institute can justifiably feel that this effort has been worth while. It will also give us a feeling of obligation to expand the number and scope of similar Short Courses.

VI. CUSTOMER RELATIONS IN THE HEATING BUSINESS

James L. Isham*

I was listed on the program as being in the public relations business. Some of you might be wondering what the correlation is between public and customer relations and I think it might be well for me to say a few words on the subject of public relations.

Most people who think they know what public relations is are inclined merely to answer, "Why, public relations is publicity." Publicity is really only part of the job. One of the best definitions of public relations that I have heard recently is that "Public Relations is the art of knowing how to get along with people — and telling it in print." The people you have to get along with in order for your business to prosper are many — they are the general public, your customer; they are your employees, your stockholders, suppliers and almost everyone else with whom you come in contact day after day. The publicity part comes when you tell of your company's activities for the public interest in print. You tell your story to the general public through the mass media of newspapers, magazines, radio, newsreels, and many more. You tell your employees or your stockholders through more personal and direct media — letters, cards, bulletin boards, company publications, pay envelope inserts.

Customer relations is just one phase of public relations — restricted to one group, your customer, and without the publicity. Not that a particularly brilliant stroke of customer relations won't result in widespread publicity — many will. We'll talk about that later.

The ultimate purpose of any customer relations program is to increase sales. It is axiomatic that you cannot improve customer relations without increasing sales. There is no set definition, no set rules to be followed in practicing good customer relations. All customer relations are based on service . . . going out of your way to do things for people. Customer relations are personal, always local . . . a thousand and one little things that defy classification.

As an example, let's turn for a moment to the hotel trade. Their entire business is selling service; they have no product to offer. There is the story of a certain midwestern business executive who spent one week out of every month in New York. On these trips he stayed at the Waldorf-Astoria. He was the kind of a customer that the hotel valued highly — a key man in industry, a big spender, etc.

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On his first visit to the Waldorf, he took the manager aside and said, "I'm a man of simple tastes, but I want what I want when I want it. At 6 o'clock every morning I expect to be awakened by a call. At 6:45, my breakfast tray will arrive and it will consist of orange juice, oatmeal, two 3-minute eggs, dry toast and coffee. I want my laundry picked up every Monday afternoon and I expect it to be back by Wednesday afternoon." The manager, who was especially eager to please this "decorative" customer, assigned one of his assistant managers to supervise this service schedule personally. Throughout the whole week, everything went beautifully; from the assistant's report, the manager gathered that the breakfast was always on time, the laundry had been taken care of as per schedule, and everything had gone exactly as ordered. This wonderful service continued during each of the executive's visits to the hotel, and every time the gentleman arrived, the manager would greet him, always hoping for some little word of praise for the kind of service that had been given. For six months, no such words were forthcoming. Finally, on the man's seventh visit to the hotel, the manager decided that there *must* be something wrong somewhere, so he decided that he would get up early and inspect the morning service personally. As the waiter was wheeling the tray from the kitchen, the manager noticed that everything seemed to be in perfect order. But then he stopped the boy and, reaching to a nearby bouquet, he picked a rose and put it on the tray. Well, the rose did it. Fifteen minutes later, the man phoned the manager and said, "For the past six months everything has been exactly as I ordered. Now, you've done a little something extra. That's what I call real service."

To get more specific about your particular business, let's take a look at today's customer relations problem in the manufacture, distribution, and sale of heating systems.

Let me point out that customer relations are doubly important in this business because of the way the average home owner selects his heating system. Chances are that he has a friend who has recently built a house and he calls him up and says, "John, what kind of heating system do you have in your house? Does it work well? It does? Then that's the kind I want." Or perhaps he's influenced by his family history in heating systems. His father always had a certain type of system, and it always seemed to work well, so he thinks he might as well have one like it.

The heating contractor and manufacturer have to make every effort to contact the customer directly. Today that's a little harder than it might sound. Homes are going up in lots of 100, 200, and 300 at a time and these homes are not usually being built by their ultimate owner, but by large building concerns. That is especially true in this Chicago area. The result is that the heating contractor has no direct contact with the customer. For a good installation, the builder takes the credit — and for any defects that crop up in the heating system, the blame is shifted to the heating contractor.

Although what I am going to propose to help solve this problem are steps that might be taken by the individual contractor, I think that the manufacturer might well take note. The success or failure of his product is oftentimes dependent on the contractor. A poor installation discredits the product itself. People remember the nameplate on that boiler and if anything goes wrong they are very likely to blame the unit. To live up to the standards that the manufacturer sets for his product, a good installation job is a necessity. So I'd like to offer the suggestion that the manufacturer might do well by setting up a similar type of customer relations program for use by the contractors who handle his line.

Here is what I have to propose for the heating contractor to make direct contact with the customer. After the building has been completed, the contractor should pay a call on the home owner and offer his services to make final adjustments of the heating system to suit that particular family's habits or tastes. I believe that this call is important at this time, not only to establish a direct contact with the customer but also to avoid your competitor's being called in when something goes wrong. There you leave yourself open for criticism. Every contractor has his own ideas on how certain things should be done. Beat the customer to the draw! Don't wait for him to call when something goes wrong.

Your attitude on this first call should be that of placing your services at his disposal. I remember what Claude Hopkins, one of the highest-paid advertising copy writers of all time, said in this regard: "Argue anything to your own advantage, and people will resist you to the limit. Seem unselfishly to serve the customer, and people will flock to you naturally."

This first call should not just be polite talk, but a thorough inspection of the whole system, followed by an actual demonstration at the unit. Briefly explain, in simplified language, every part of the system and the purpose it serves. Explain the controls and the safety features. Tell them the purpose of the thermostat and what actually happens when you turn it up. Explain the aquastat. You might even give a practical demonstration by turning the aquastat down low and showing them how it automatically turns the unit off when unsafe high temperatures are reached. These explanations are going to pay dividends later, because in many cases when a customer calls concerning trouble with the system, he can identify the faulty part by name.

At this first visit, let your customer know exactly what to expect of the unit. Tell him exactly how long it is going to take to heat the house in the morning after having the thermostat set at, say 60°, during the night. It will save you trouble later if the customer understands that it is going to take longer than five minutes to warm the house. That is one of the primary principles of all public relations — explain *before* anything has actually gone wrong. It is much easier that way.

If in the summer, explain how to turn on the pilot. Your written instructions on how to do this are frequently used to wipe dirty hands on. It is much easier for a man to listen for five minutes to a competent person than wade through written steps 1 to 15 on how to do it. If the heating season approaches, actually turn on the pilot. Tell him what care and cleaning the unit is going to need.

You might even take notes of criticism about this heating system — not that you can do anything about it at this time, but for future use in some of the homes yet to be built. His criticism might be very valuable, but even if it is irrelevant, the point is that you flatter him by asking. You've put him in the position of a heating authority.

You must not take up much of the customer's time! Be brief and simple and always at his service. You can save time by studying the individual heating system before making the call.

I think such a call would be appreciated. I've recently bought a new house, and I don't have the slightest idea who my heating contractor is. The only contact I have had with him is when some man with muddy feet walked over my living-room rug to adjust the thermostat.

As a natural follow-up to this initial call, I suggest that you set up a regular inspection schedule. Heating contractors have year-'round employment. Unfortunately, part of this year is spent in a mad rush and part in a very slack season. Make use of your slack season. Don't wait until a customer calls you — chances are that it would be on the first cold day, in your busiest season when everyone else is calling in, and you'd have to put him off three or four weeks or turn him down altogether. I would say that the inspection charges for this sort of visit should be kept at the barest minimum. Of course, for actual adjustment or repair, charge him the regular rates.

I would suggest that you contact this customer by correspondence to set up your inspection at his convenience. A personal letter is preferred to a postcard. Postcards can be very convenient, with regular blanks to be filled in. But so many people have been using postcards as a direct mail medium that I believe they have a commercial stigma attached to them. They are not as likely to be read as a personal letter signed by one of the top men in the company. For the customer's convenience, you can ask him merely to write the time he would like you to call in the margin of the letter and return it to you. Such an inspection schedule would save you money and help build a company reputation of good alert service.

However, I'm not here to sell any one specific program based on a surface knowledge of your business. My purpose is to create a "feel" for good customer relations. Toward that end, I have gathered some good examples from other businesses in an attempt to show in a practical way just what good customer relations consists of. The thought behind all of these examples is applicable to any business.

There is one problem which is common to all types of business — that of credit. There is no spot where a man is more sensitive than his personal credit. I think Marshall Field & Company offers a splendid example of customer credit relations. Field's works on the theory that people usually hear from a credit manager only when they owe money. They keep a step ahead of the customer by writing him certain letters in appreciation of his patronage in the past.

On the first anniversary of the opening of an account — if the customer has paid his bills fairly promptly and doesn't have a reputation for excessive return of merchandise — he is likely to receive this letter:

> One year ago this month you established a charge account with Marshall Field & Company. We have marked the approach of this anniversary with pleasure.
>
> Your patronage during the year just past is an evidence of your confidence in us, and we wish to say "thank you."
>
> In the future, as now, we hope to retain your continued regard.

After three, five, ten or twenty-five years, he is likely to receive this letter:

> Do you remember when you first opened your charge account with Marshall Field & Company?
>
> You have been one of our charge customers for many years — to be exact, since 1918 — and we are proud of the confidence you have shown in us.
>
> We believe that we can best show our appreciation of your long patronage by maintaining the ideals and traditions which won your friendship so many years ago.

> To this end, we shall direct our efforts, as always, toward making your shopping here pleasant and enjoyable.
>
> We hope that we may continue to serve you for many years.

If a charge account suddenly becomes inactive, which might indicate that the customer is irritated with the company for some reason, this letter is sent out:

> A recent survey has brought to our attention the fact that you have not used your charge account in recent months. We are concerned about this and are interested in any reason there may be for it.
>
> Do you feel that we have been in error? If so, please use the reverse side of this letter to tell us about it. When we know the difficulty, we shall be able to take steps to prevent its recurrence.
>
> Perhaps you are unable to visit the store at this time. If you like, our Personal Shoppers will be happy to make selections for you. Your mail or telephone orders will receive their prompt and expert attention.
>
> We have enjoyed being of service to you in the past, and we extend to you a sincere invitation to make use of your charge account again.

On serious complaints, especially when Field's suspects that some subordinate in the credit department has mishandled an account, the customer receives a personal call from the credit manager. Last month, an executive of the credit department traveled clear out to Ottumwa, Iowa, to correct a misunderstanding. It is not uncommon for Field's to send a man up to Michigan or Wisconsin to maintain customer goodwill in such cases.

Not to confine all my kudos to Field's I'll skip down State Street to Carson Pirie Scott & Company. This, I believe, is a marvelous example of going out of one's way in credit matters: I have a friend who was confined to the hospital for some two months. He was very close to death. His wife was naturally too preoccupied to think of such routine matters as the paying of bills. A bill from Carson's went ignored on the first month. As I recall, at the beginning of the second month, she received a polite letter remarking that her remittance had not been received. This was ignored, too. During the third month, after the man had pulled through and was on his way to recovery, she sat down to straighten out her affairs, and with her remittance to Carson's she wrote the credit manager a note of explanation. Carson's could have marked the bill paid and let it go at that. But instead, they went a little farther. The woman received a letter from the credit manager, stating that it was perfectly excusable that the bill was late, and that they were very sorry to hear her husband had been ill, and sincerely hoped that he was well on the road to recovery. They did something just a little extra and that woman has remembered that gesture for years.

In your business, customers are seeking information. See that it is easy for them to get. Aside from advertising and straight selling, what service angles can you use to get the information to the customer?

Here are some of the ways used by other businesses. Going back to Marshall Field's again: the store has a group of hostesses — attractive young girls, outfitted in trim suits by Adrian of Hollywood — who are stationed at various points throughout the store. If a customer can't find what he is looking for or has some other question, he doesn't have to go to a centrally located information booth. These hostesses *bring the information to him.* Any male wandering aimlessly through the store with a dubious look on his face is immediately accosted by the hostess, who offers to answer any of his questions.

There is a remarkable shop in Field's store called the "Tip-to-Toe" Shop. They have phenomenal files of information on weather, customs, and clothes for any city, state, resort, or country in the world. A woman can go to this shop and find out exactly how many rainy nights there are in Rio in the month of September, or whether they are dressing for dinner this year at Lake Placid. The shop will tell her exactly what clothes she will need wherever she is going. Not only that, she can secure her entire wardrobe from a comfortable easy chair. Girls are sent to every department in the store to gather merchandise for her selection.

The husband of a southern matron was running for governor. The woman was not accustomed to public life and had no idea what to wear for the inauguration if her husband won. Her husband did win and Field's outfitted her not only for the inauguration, but for the entire spring season.

Correspondence offers a very important opportunity for creating goodwill for your company. If a customer sends you an order for something that is unavailable at the time, don't just merely state that the item is unavailable and let it go at that. Tell him why you haven't got it, what the prospects are for getting it, and perhaps offer suggestions as to how he could best go about getting his order filled. Answer everything to your correspondent's complete satisfaction — and answer it promptly! Don't make him wait for three or four weeks.

Don't send form letters. They're deadly. Forbes Magazine pulled an ingenious stunt with a form letter not long ago. They purposely made an error in one letter of one word while running the letter through the Multigraph, and then had one of the office girls go through each letter with her pen, making the correction. This way, it looked as if each letter had been individually typed.

There are many nice little things that you can do for people above and beyond the call of mere satisfactory service. A casual mention to a Cincinnati hotel manager that I was old-fashioned and liked rocking chairs brought about the delivery of a rocking chair to my room the next morning.

I am going back to Carson Pirie Scott & Company, and the woman with the sick husband, to point out another wonderful example of going out of your way in service to the customer. After the man returned home from the hospital, he was still confined to his bed for another month. He had read everything in sight, and all the books at the local gift shop. You might be familiar with Autobridge — regular sets of playing hands are printed on sheets of paper to be used in the device. The local gift shop had only one set of these hands. The man breezed through these in one evening. The next morning, the lady phoned a personal shopper at Carson's, explained the situation, and requested that more Autobridge hands be sent to the apartment. To say that Carson's delivered them promptly is an understatement. The hands arrived exactly one hour later — by special messenger.

Here are a couple of ingenious things for the factory executive to consider. I remember a reception room of a large printing plant in St. Louis. On the wall there was a sign that said in big bold letters, "We like salesmen." And then it went on to say that salesmen brought the world to their door; that salesmen enabled these company executives to keep up with the latest advancements and business trends; and that they were welcome at any time. I remember that distinctly, because at that time I was a young job-seeker fresh from college. I'll bet that sign has made friends of thousands of similar callers to that plant.

Another reception-room trick is used by a small Milwaukee manufacturing plant. In the reception room are many copies of a little booklet with the simple cover inscription, "Hello." Inside, it gives the caller pertinent information on the background, the duties, and even the hobbies of the company's key personnel. Thus, a caller can be prepared to make a sale even before having a chance to size up his prospect personally. The book also tells of the company's products and important facts about the company itself.

There are many opportunities for customer relations which cannot possibly be planned in advance. Taking advantage of such opportunities often results in widespread publicity for the company.

As an example, the Caterpillar Tractor Company of Peoria is very conscious of its social obligations in the community in which it operates. Not long ago, a group of boys of pre-high school age were working like little beavers to level a vacant lot for a baseball field. The lot was full of bumps and weeds, and each boy had a shovel or a pick, trying to do the whole thing by hand. About an hour after they had started, a shiny, bran-new Caterpillar bulldozer pulled on the field and leveled the whole thing for them in an hour. A Caterpillar employee had seen the boys working on his way to the plant and had spoken to the right person, who dispatched the bulldozer to the field. That story, because of its human interest elements, was carried in newspapers from coast to coast.

Down in southern Indiana about six weeks ago, a train struck and killed a boy's dog. The train stopped, and the conductor and the flagman and the whole crew went back and saw how crushed the boy was at the loss of his pet. A week later, they all chipped in, bought the boy a new dog, and stopped the train near his home to deliver it personally. That's another example of seizing an opportunity to build goodwill for a company, not only in its own locality but nationally. This story was flashed all across the nation.

There are several trite expressions which, because of their frequencies of use, have lost all their value. One of these is "the customer is always right." Frederick Williams, president of Cannon Mills, in addressing a national sales meeting of that organization, said the same thing in much more specific language. His talk was entitled "What Is a Customer?" I am going to read some of his definitions to you.

"A customer is the most important person ever in this office — in person, by mail, or by telephone."

"A customer is not dependent on us — we are dependent on him."

"A customer is not an interruption of our work — he is the purpose of it. We are not doing him a favor by serving him — he is doing us a favor by giving us the opportunity to do so."

"A customer is not an outsider to our business — he is part of it."

"A customer is not a cold statistic — he is a flesh-and-blood human being with feelings and emotions like our own, and with biases and prejudices."

"A customer is not someone to argue or match wits with. Nobody ever won an argument with a customer."

"A customer is a person who brings us his wants. It is our job to handle them profitably to him and to ourselves."

"Let us not forget that anyone who will visit us, anyone who will call us on the telephone, anyone who will seek our aid, offers to us the

privilege and the opportunity of creating goodwill for Cannon. Let us not throw away that privilege. Let us never rebuff the man who gives opportunity."

"Customers are the greatest asset of any business. They provide the whole purpose of business enterprise. Guard them well, and satisfy their wants so effectively that they will want to come back 'again and again and again'."

"And keep in mind the U.S. Supreme Court's definition of goodwill: 'The disposition of a satisfied customer to return to the place where he has been well treated'."

I hope that by the examples I have quoted I have been able to give you some idea of what good customer relations consists of. It usually boils down to common sense. And remember, it's not just having the idea, but actually carrying through.

Some wag asked me last week: "What good is happiness? You can't buy money with it." Well, you *can* buy money with happiness, if you make the right people happy . . . and making those people happy is the good art of customer relations. Treat 'em well . . . go out of your way . . . and with their happiness — buy money!

VII. INDIRECT HEATING OF DOMESTIC HOT WATER

Ross J. Martin*

When a home is heated with a hot water or steam heating system, it is possible to use the house heating boiler to supply hot water for domestic uses. The advantages claimed for this method of producing domestic hot water are: (1) an ample supply of hot water is available at all times; (2) fewer units of mechanical equipment are required; (3) the cost of producing hot water by this means is low; (4) the equipment required can be installed in a minimum amount of floor space; and (5) the life expectancy of the heating system is increased because summer shutdown periods are avoided.

Before the correct size and type of equipment can be selected and installed for the indirect heating of domestic hot water, it is necessary to know the output and performance characteristics of the heater and, when used, the performance characteristics of the storage tank and connecting piping. Data of this kind were very meager until recent tests were made at the I=B=R Research Home under a cooperative agreement between the Institute of Boiler and Radiator Manufacturers and the Engineering Experiment Station of the University of Illinois. The results of these tests have been published in University of Illinois Bulletin 366. Also, under this cooperative agreement, the University has been developing testing and rating codes for the various types of indirect heaters. These codes will insure a uniform basis for selecting heater sizes.

Figure 1, from Bulletin 366, shows the layout of the test equipment. The tests were conducted with a boiler consisting of three 4-in. cast iron sections insulated on the front, back, sides, and top and completely encased in a sheet-metal jacket. This boiler had a net I=B=R rating of 63,000 B.t.u. per hr., and a gross I=B=R rating of 95,000 B.t.u. per hr., when fired at the rate of 1.0 gal. of oil per hr.

The indirect water heater was of the trombone type, consisting of three $\frac{3}{4}$-in. copper U-tubes that extend into the boiler a distance of 21 in. The water heater was located in the back section of the boiler, approximately 31 in. above the bottom of the water leg and 4 in. above the location of the low-limit control.

A standard 30-gal. storage tank, 12 in. in diameter and 60 in. long, was suspended in a horizontal position near the basement ceiling. The sides of the tank were insulated with air-cell insulation 1 in. thick,

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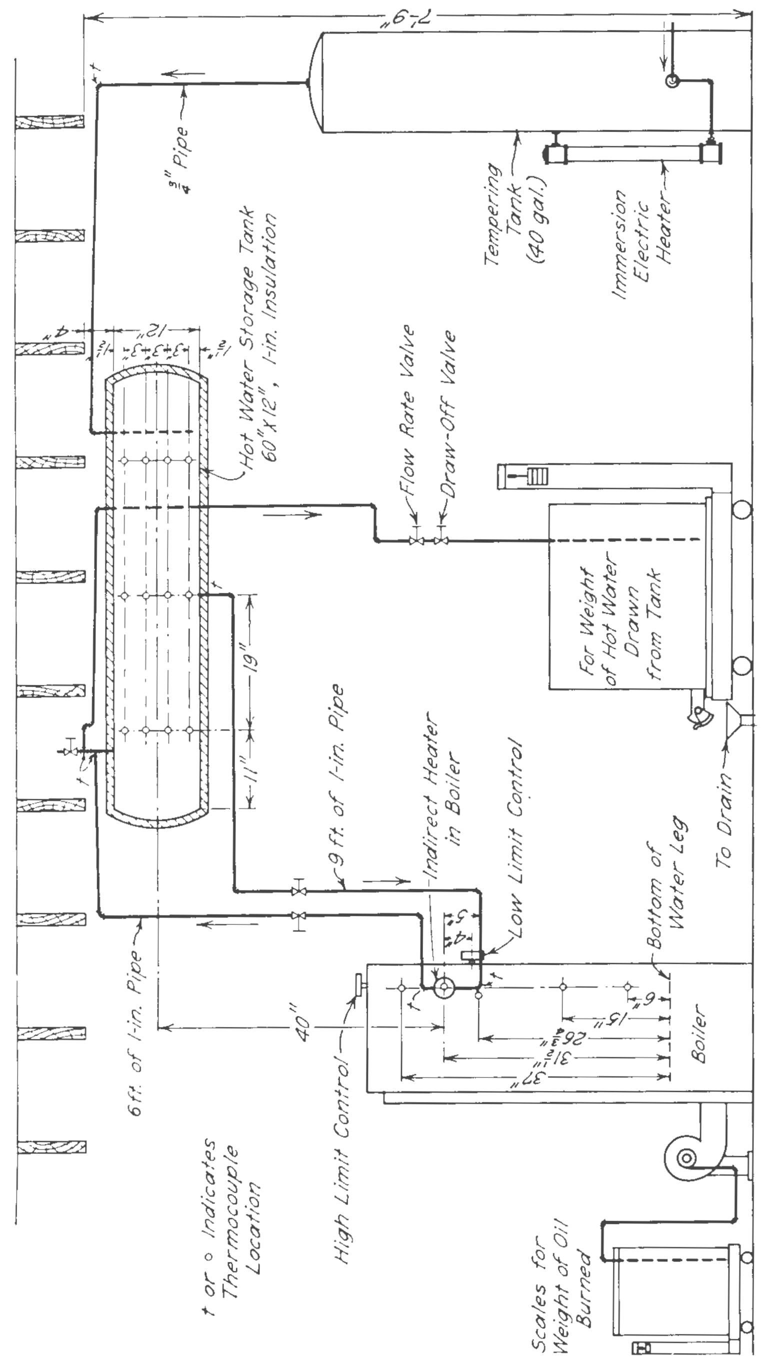

Fig. 1. Diagram of Test Equipment

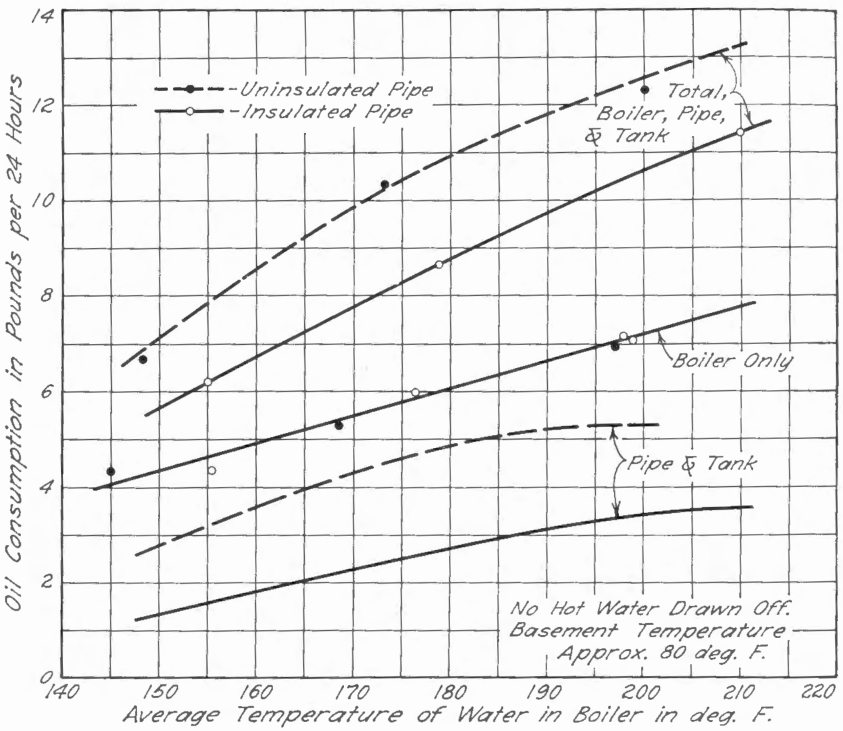

Fig. 2. Stand-by Oil Consumption Curves

and the heads were covered with 1 in. of magnesia insulation. Details of the piping connections of the tank and heater, and of the location of the thermocouples used to measure the temperature of the water in the system, are shown in Fig. 1.

Because space heating is required only during the winter months whereas domestic hot water is required the year around, it was necessary to run separate sets of tests under winter and summer conditions to obtain complete performance characteristics of the heater.

During the summer months the cost of producing domestic hot water is influenced by the daily fuel consumption chargeable to: (1) heat losses from the boiler; (2) heat losses from the storage tank and piping; and (3) the actual heating of various quantities of hot water. The heat losses from the boiler, storage tank, and piping can be grouped together and termed stand-by losses. To evaluate these stand-by losses two series of tests were run, one with the 15 ft. of 1-in. pipe connecting the water heater and the storage tank uninsulated and the second series with this pipe insulated. In each of these series, separate tests were conducted to determine the stand-by losses of the boiler, and of the piping and storage tank, when the low-limit control was set at various settings from 145 deg. F. to 210 deg. F. Figure 2 illustrates these stand-by losses for various boiler water temperatures for the two series of tests. It can be seen from this curve that insulating the piping results in an approximate saving of 2 lb. of oil per 24 hr. when no water is drawn off. An additional advantage is realized with the insulated piping, due to the higher average water temperature in the storage tank with a given boiler water temperature. The tests indicated that the boiler water temperature was about 20 deg. F. higher than the storage tank water temperature when insulated piping was used, and that an increase of 3 to 5 deg. F. in the boiler water temperature was necessary in order to maintain the same storage tank water temperature when the piping was uninsulated.

It is interesting to note the amount of heating load imposed on the boiler when a storage tank of cold water is permitted to circulate

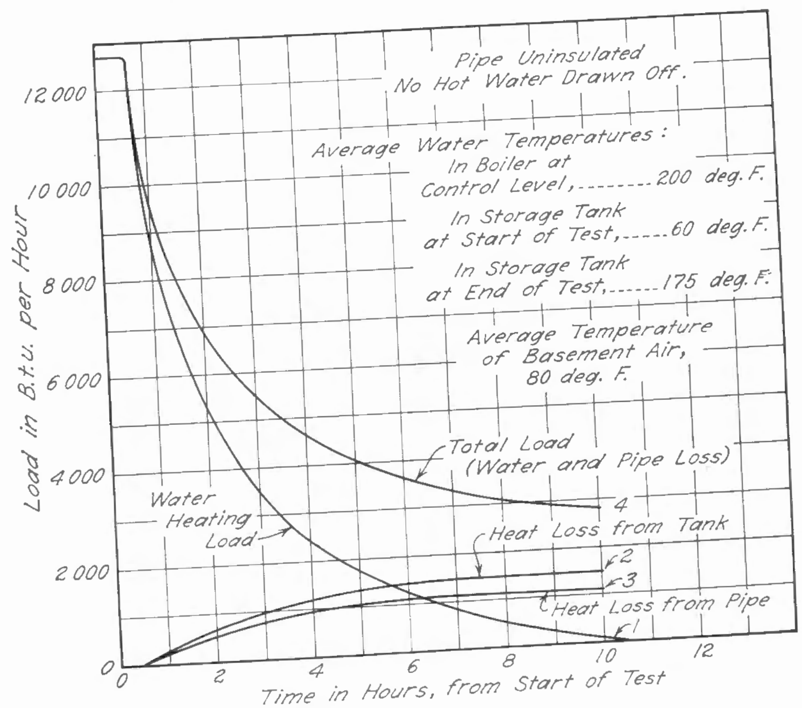

Fig. 3. Water Heating Load During Heating-up Period

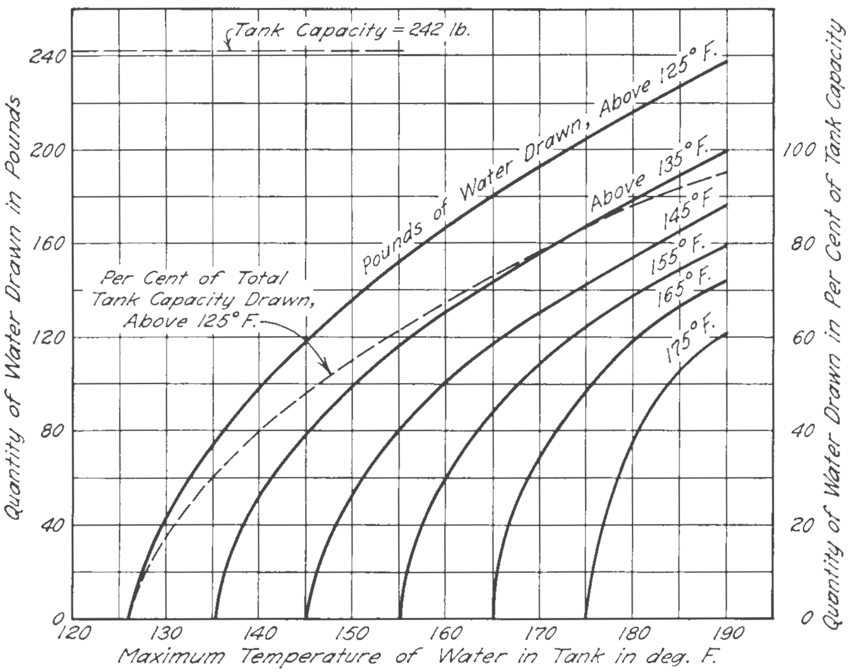

FIG. 4. HOT WATER AVAILABLE AT A SINGLE DRAW-OFF

freely through the water heater immersed in a boiler being maintained at a given temperature.

Figure 3 illustrates the variation of the load on the boiler with time, for a particular set of initial conditions. It can be seen that the load imposed on the boiler for water heating alone decreases rapidly as the temperature of the water in the storage tank increases. The heat loss from the tank and piping increases as the temperature of the water in the storage tank increases. Tests for other initial conditions indicate a similar relation between the boiler load and time.

When the water in the storage tank had been heated to a given temperature, there was a given amount of water that could be drawn from the tank before the water was cooled below a usable temperature. Figure 4 shows the amount of water available above a given temperature for various initial storage tank water temperatures. If 125 deg. F. is the required minimum temperature, the dotted curve indicates the per cent of the total tank capacity that could be drawn off before this temperature is reached. The rate of draw-off for these tests was approximately 5 gal. per min. The results have very little relation to the

TABLE 1

HOT-WATER DRAW-OFF SCHEDULES

Hours from Start of Test	Water Drawn Off, lb.			Hours from Start of Test	Water Drawn Off, lb.		
0	17	0	0	9	0	0	0
1	42	83	83	10	17	17	25
2	25	58	83	11	17	25	42
3	8	25	100	12	25	33	42
4	17	25	42	13	0	0	0
5	17	25	42	14	50	83	83
6	17	42	83	Total lb.	252	416	625
7	0	0	0	Total gal.	30.2	50.0	75.0
8	0	0	0				

Start of draw-off test — at end of last burner on-period.
End of draw-off test — at end of last burner on-period, approximately 24 hr. after start of test.

performance of the water heater itself, but are useful in estimating the required tank size when the maximum draw-off is known. This type of test is also useful in comparing the mixing action in storage tanks placed in the horizontal and vertical positions.

In order to obtain data necessary for the prediction of the fuel consumption under service conditions, one series of tests was made in which, at various intervals during the day, quantities of hot water approximating those used in actual service were drawn from the storage tank. The three draw-off schedules used are given in Table 1. It is true that the actual demands encountered in service will deviate from the test schedules used. However, other investigations have shown that, within certain limits, the actual schedule of draw-offs has practically no effect on the service efficiency, and hence on the daily fuel consumption, as long as the total quantity of water used during the day remains unchanged.[1]

Tests were made at three different boiler water temperatures, using each of the three schedules given in Table 1 for each setting. Each test was started at the end of a burner on-period, after the system had operated on stand-by sufficiently long to establish equilibrium conditions. After the last draw-off, as listed on the schedule, the system was allowed to operate under stand-by conditions with no water drawn for the remainder of the 24-hr. period, at which time the test was stopped at the end of the burner on-period.

Comparison between the fuel consumption required to supply a given quantity of hot water when uninsulated piping is used between the water heater and tank, and that required with insulated piping, can be made only when the water in the storage tank is maintained

[1] "Fundamentals of Domestic Gas Water Heating." American Gas Association. Bul. 9, p. 150.

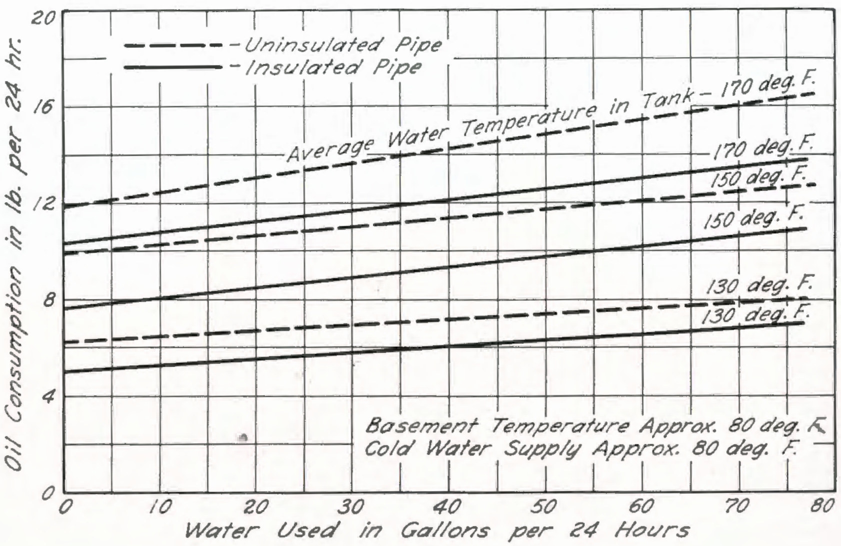

FIG. 5. DAILY OIL CONSUMPTION BASED ON QUANTITY OF WATER USED—SERVICE DRAW-OFF TESTS

at the same temperature in both cases. Since the operation of the burner was regulated by a temperature control located in the boiler, the daily fuel consumption for each test was plotted against the average temperature of the water in the storage tank, and these curves were then used in connection with the three draw-off schedules to determine the daily fuel consumption that would have been obtained for any given tank temperature. The results, showing the daily fuel consumption at three different water temperatures and for all daily draw-off rates from 0 to 75 gal. per day, when operating both with and without insulation on the piping connecting the water heater to the storage tank, are presented in Fig. 5.

From the curves of Fig. 5 it may be observed that the daily oil consumption chargeable to heating water was reduced by amounts ranging from 1 to 2.5 lb. per day, by simply insulating the 15 ft. of 1-in. pipe connecting the water heater to the storage tank. In other words, under conditions of summer operation, insulating the connecting piping resulted in a 15 to 20 per cent reduction in the fuel consumption required for heating water for domestic uses, and at the same time somewhat reduced the amount of heat escaping into the house from the piping and chimney. In the summer this heat loss from piping and

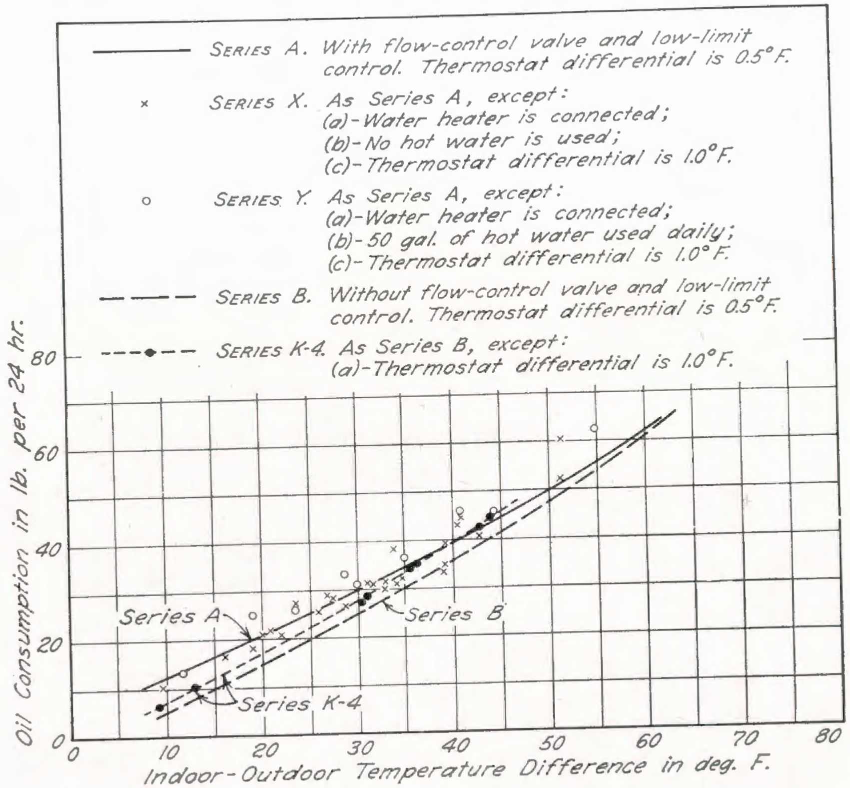

FIG. 6. DAILY OIL CONSUMPTION FOR BOTH HEAT AND HOT WATER

chimney is undesirable in that it raises the temperature in the living quarters, but in the winter most of it is regained by being utilized to offset part of the heat loss from the house.

Under summer conditions the water heating load is the only load on the boiler, and the only heat that can be regarded as useful is that portion in the fuel burned which is utilized in raising the temperature of the hot water consumed. During the winter the main load on the boiler is the house heating load, and a large portion of the heat that escapes from the surfaces of the boiler, the chimney, the storage tank, and the piping—which is lost heat as far as summer operation is concerned—is utilized in supplying heat to the house. Accordingly, several series of tests were run in order to obtain data on winter performance; the results are shown in Fig. 6. Series A and B have been discussed in detail in earlier reports.[2] Hence at this point it is sufficient to observe that, for any given indoor-outdoor temperature difference, the excess in the amount of fuel burned for series A over that for series B was attributed to that required to maintain a sufficiently high temperature in the boiler to enable it to be used as a means of heating domestic hot water. Since the internal water heater was not connected to the hot-water storage tank during these tests, the oil consumption does not include any fuel chargeable to the stand-by loss from the storage tank and piping, or to the actual heating of water for domestic uses.

Two additional series of tests were therefore run, in which the water heater was in operation, and the control system was the same as that used in series A. For series X, shown by the points marked *x* in Fig. 6, no domestic hot water was used. For series Y, shown by the points marked *o*, 50 gal. of hot water were drawn each day in accordance with the schedule given in Table 1. It is evident that the curve for series A represents these points equally well. In other words, practically all of the heat losses from the hot-water storage tank and piping were recovered and utilized in heating the house. Thus, with the boiler used both to supply domestic hot water and to heat the house, the only additional fuel required to supply domestic hot water over that required for house heating alone was that necessary to offset the additional heat loss from the chimney. This additional heat loss from the chimney was brought about by the fact that, in mild weather, in order to heat the domestic hot water it was necessary to maintain the water in the boiler at a higher temperature than that which would have resulted if there had been no flow-control valve and low-limit control. With the latter arrangement, the boiler water would have been permitted to cool during times when there was no heat demand from the room thermostat. This condition is represented by the curve for series K-4.

It is very difficult to estimate the average yearly cost of heating water for domestic uses with the house heating boiler, because of the number of unknown variables involved. The principal variables are: (1) the unit cost of the fuel; (2) the average quantity of water used per day; (3) the temperature of the water; (4) the type of heater installation; (5) the method of control; and (6) the fuel used. The unit cost of fuel can be eliminated if seasonal fuel consumption is substituted for cost. Figure 5 shows that the quantity of water used does

[2] "Performance of a Hot-Water Heating System in the Research Home," ASHVE Transactions, Vol. 48, pp. 169-72.
"Performance of a Hot-Water Heating System in the I=B=R Research Home at the University of Illinois," Univ. of Ill. Eng. Exp. Sta. Bul. 349, pp. 22-25, 30-32. 1944.

TABLE 2
DISTRIBUTION OF AVERAGE OUTDOOR TEMPERATURES AND CORRESPONDING FUEL CHARGEABLE TO HEATING WATER

Average Outdoor Temperature	Total Number of Days[1]	Average Number of Days per Year	Oil Required to Heat 50 Gal. of Water Daily, lb.	
			Per Day	Total
1	2	3	4	5
−10 to −5	1	0.2	0	0
−5 to 0	2	0.4	0	0
0 to 5	4	0.8	0	0
5 to 10	11	2.2	0	0
10 to 15	23	4.6	0	0
15 to 20	38	7.6	0	0
20 to 25	68	13.6	0	0
25 to 30	127	25.4	0	0
30 to 35	169	33.8	0	0
35 to 40	150	30.0	1.5	45.0
40 to 45	117	23.4	2.0	46.8
45 to 50	113	22.6	3.0	67.8
50 to 55	104	20.8	4.2	87.4
55 to 60	99	19.8	5.0	99.0
60 to 65	110	22.0	7.2	158.3
65 to 70	95	19.0	9.0	171.0
70 to 75	68	13.6	9.8	133.3
75 to 80	47	9.4	9.8	92.1
80 to 85	17	3.4	9.8	33.4
85 to 90	2	0.4	9.8	3.9
		273		938.0 lb. = 134 gal.

[1] Based on records of United States Weather Bureau Station at University of Illinois, Urbana, Illinois. Includes months of January, February, March, April, May, September, October, November and December from September, 1936, to May, 1941.

not greatly affect the fuel consumption. On the other hand, the latter is greatly influenced by the temperature of the water. During the winter months the boiler at the I=B=R Research Home was operated so that it maintained a temperature of 150 deg. F. in the storage tank, and, on the assumption that the average family of four uses about 50 gal. of hot water per day, the curves of Fig. 6 provide a means for estimating, at any given outdoor temperature, the daily fuel consumption chargeable to heating water. For the purposes of analysis, it has been further assumed that insulated piping would be used between the storage tank and heater.

The frequency of the different outdoor temperatures occurring during the nine months of the heating season in Urbana, Illinois, is shown in Table 2. The data for this table were obtained from records of the United States Weather Bureau Station at the University of Illinois, Urbana, Illinois, for the nearly five years from September, 1936, to May, 1941, inclusive.

Column 4 shows the estimated daily fuel consumption chargeable to heating 50 gal. of water daily, obtained from the difference between the curves for series K-4 and series Y in Fig. 6, corresponding to indoor-outdoor temperature differences represented by the mean temperature of each bracket shown in column 1. The total fuel consumptions shown in column 5 were then calculated by multiplying the daily fuel consumptions (column 4) by the average number of days per year having average temperatures falling within the limits of each bracket (column 3). The total of column 5 represented an estimated seasonal oil consumption of 938 lb., or 134 gal. for one winter's operation.

During the three summer months, a daily fuel consumption of 9.8 lb. of oil can be estimated from Fig. 5. The total estimated fuel consumption for the three summer months would therefore be $92 \times 9.8 = 902$ lb., or 129 gal. of oil, and the estimated yearly fuel consumption would be $134 + 129 = 263$ gal. At a cost of 7¾ cents per gal., this estimated fuel consumption represents a total cost of $20.38 per year, or an average cost of $1.70 per month exclusive of the cost of operating the burner. Under the conditions of the tests in the I=B=R Research Home, the electrical input to the burner was at the rate of 118 watts and the rate of oil burning was 1.07 gal. per hr. of operation. The total burner operating time chargeable to heating water would therefore be $263 \div 1.07 = 245$ hr., and the total power consumption would be $245 \times 0.118 = 28.9$ kw-hr. At an average cost of 3½ cents per kw-hr. for electricity, the cost of power would be $1.02 per year, or approximately 8 cents per month, representing a total estimated average monthly cost of $1.78 chargeable to heating water by an indirect storage type heater installed in a house heating boiler similar to the arrangement used in the I=B=R Research Home.

It was necessary to analyze the data taken at the Research Home on the basis of water in the storage tank at 150 deg. F. However, by some agencies it is considered that a temperature of 140 deg. F. is sufficiently high for all practical purposes. In the latter case, most of the reduction in the cost of heating water would be brought about by conditions prevailing during the summer months.

Data on winter operation were not sufficient to make a complete analysis of the costs with storage tank temperatures of 140 deg. F. However, it can be shown from the curves in Fig. 5 that a saving of approximately 18 per cent can be effected in the summer by using water at a temperature of 140 instead of 150 deg. F. Since the winter savings would be materially less, an estimated yearly saving of approximately 10 per cent seems reasonable. On this basis an average monthly cost of approximately $1.60 might be expected if water at a temperature of 140 deg. F. were used.

VIII. PUMPS AND CONTROLS

S. R. Lewis*

We have to do with the mechanical apparatus used for moving liquids in heating and ventilating and cooling systems for buildings.

The primary service of a pump is to develop a difference in pressure between the liquid at its inlet and the liquid at its outlet. If the pump will accomplish this differential and if it is connected with a pipe, the liquid must flow through the pipe in an attempt to establish equilibrium.

A very early pump is attributed to Archimedes. It is like a piece of hose coiled like a snake around a pole that has its axis on an incline. As the open lower end of the hose is dipped into water some water enters, and if the pole is revolved, some water runs along the hose and ultimately reaches the upper end and outlet, where the water emerges at a level higher than that at which it entered. The water at the higher level would run back to rejoin the water at the lower level if given a chance, and thus it will be seen that the Archimedes pump in operation has created a pressure differential.

The old chain pump occasionally to be seen in a farmer's well has a series of cups that dip into the water at the bottom and that are emptied at the top as they follow the chain around the upper sprocket wheel. This pump thus creates the desired differential pressure.

A pipe submerged below the water surface in a deep well, if connected near its bottom by a small pipe that discharges compressed air, will deliver water in large quantities at the top of the well; again creating a differential pressure.

A stream of water flowing through a nearly horizontal pipe at very low speed, if suddenly stopped, as by a lift check valve, develops a substantial shock-pressure, and this pressure will easily force a small part of the main stream upward for a considerable distance. If the performance cycle of alternating flow and sudden stop is repeated, a pulsating but very useful volume of water will be pumped to a high level. Thus we have the hydraulic ram that operates for years on end to deliver spring water uphill for many a farmer.

Another useful farm device is called a pitcher pump. It comprises a vertical cylinder and a reciprocating piston. There is a suction pipe having its end submerged in the water. There is an upward-opening leather check valve at the lower end of the cylinder, and a similar

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valve in the piston itself. Water must be poured into the cylinder to seal the seats of the valves and the leather packing of the piston. After this, if the pump handle is worked with vigor, the air between the water in the well or cistern and the pump will be so reduced that water rises in the suction pipe to the lower check valve and enters the cylinder on the up-stroke of the piston. The water, unable to flow back due to closure of the lower check valve, will be forced upward on the down-stroke through the check valve in the piston. Pitcher pumps can lift only water on the suction side, to a height sufficient to balance atmospheric pressure. If the cylinder of such a pump is so far above the water level in the well that atmospheric pressure, less friction in the piping and resistance of the valves, cannot force the water up into the cylinder, the scheme will not work.

Atmospheric pressure normally is balanced by a column of water 33.9 ft. high at 62 deg. The practicable lift for a suction pump, however, due to the pipe friction plus the work of lifting the check valves, usually is limited to about 24 ft. If the well contains hot water (few wells, but many heating system tanks do), the practicable suction lift of any pump diminishes rapidly, since water when hot is very easily changed from liquid to gas, and since water pumps are not usually good gas pumps.

Reciprocating or displacement pumps have a very useful place in engineering, but inherently operate at slow speed, and when propelled by electric energy must usually have gears or belts. Gears are inclined to be noisy, and belts eventually wear out, so that a relatively high speed direct-connected centrifugal type of pump is especially desirable for electric motor drive. The conventional centrifugal pump has its inlet at the axle, and has a comparatively narrow impeller within a scroll-shaped housing like a snail shell. There are almost countless variations in the design of the impeller and in the shape of its blades. Centrifugal pump impellers in general are like fan wheels, and the capacity and efficiency are sensitive to very slight variations in curvature, thickness, and surface of the vanes. There may be several stages of pressure-increase, the discharge outlet of one impeller connecting to the inlet of the next one until an enormous ultimate pressure may be developed. The impeller of a small centrifugal pump used in circulating hot water may be fitted so loosely within the housing that liquid may flow through freely when the pump is not running, or may be so closely fitted and may have so many stages that an absolute suction pressure as low as 25 in. of mercury will be maintained.

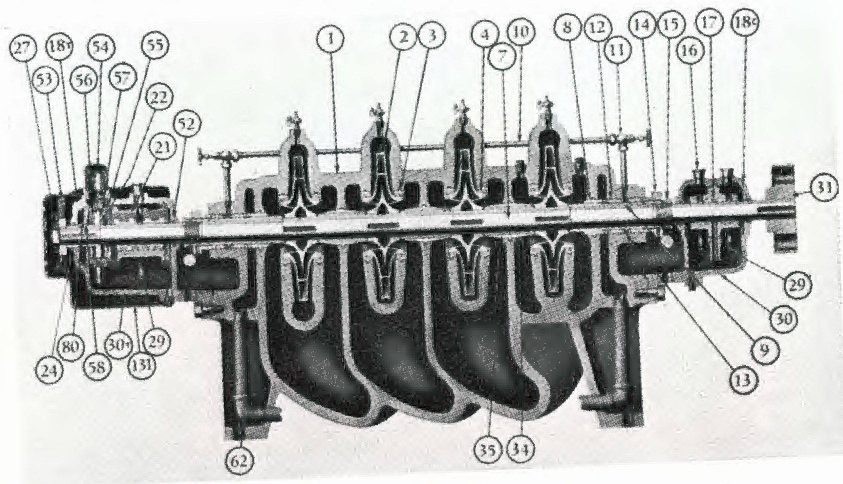

FIG. 1. SECTION THROUGH A FOUR-STAGE CENTRIFUGAL PUMP

Figure 1 shows a section through a four-stage centrifugal pump such as is used to feed high-pressure steam boilers. The casing (1) usually is of cast iron. The runners (2) may be of bronze. The power is applied at the flange (31) at the right end of the shaft. The inlet to the pump is at the right-hand end, and the outlet is through the round bottom scroll of the left rotor. Each rotor has a double inlet, so that end thrust is partly equalized, but there is an air-cooled thrust bearing at the left end of the pump.

Centrifugal pumps with single impellers may receive at their inlets, from the entering liquid, a decided thrust along the shaft. To counteract this thrust two impellers and essentially two pumps sometimes are mounted back to back so that the thrust effects balance each other. This, however, involves special housing construction and special packing arrangements around the shaft. Ball and roller bearings are more and more being used in centrifugal pumps. In many close-coupled types the pump impeller is carried on the bearings of the direct-connected electric motor, thus avoiding the necessity for a flexible shaft coupling, and requiring only one shaft gland. Where the pump is equipped with its own independent bearings, a flexible shaft coupling is desirable. Wear of the shaft at the water-tight packing gland is an inherent maintenance characteristic of most centrifugal pumps. Some slight leakage of water through the packing is generally expected and accepted. Vertical shaft centrifugal pumps are employed successfully to lift sewage from low-lying pipes and to force it into

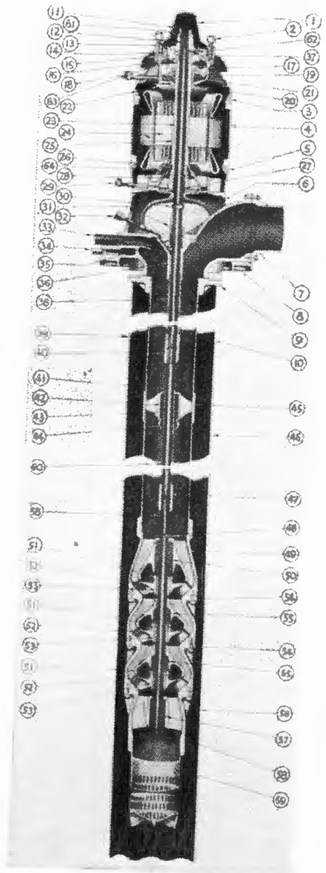

FIG. 2. SECTION THROUGH A TYPICAL DEEP-WELL PUMP

the street mains. They are also used for lifting water from deep wells. In these deep-well services the pump shaft runs down at the center of the column or water-delivery pipe and has bearings at frequent intervals so arranged that the water can pass by them with minimum resistance. The bearings may be of metal, grease-lubricated, which grease of course can affect the water only to an exceedingly slight extent, or may be of rubber, receiving lubrication from the water alone. There may be several impellers and encasements placed in series one above another.

Figure 2 is a section through a typical deep-well pump. At the bottom is a rust-resisting screen to prevent entry of gravel. The discharge outlet is at 7 on the right. The vertical-shaft motor is at the top. It is shown with a weatherproof cover and may be exposed out-of-doors. Above the screen there is a suction bowl and first impeller (56), and above this there are three successive rotors to force the water upward to the surface.

In a deep-well pump the impellers and their housings are not snail-shell type volutes, but, accepting water close to the axle of each impeller, they discharge it all around the edge of each housing, called a bowl, whence the water is led with minimum turbulence to the inlet of the next successive impeller. Vertical shaft motors for these pumps are often located out-of-doors in weatherproof housings.

Pumps for fuel oil are often of interlocking gear type, combining the positive displacement advantages of reciprocating pistons (and their tendency for relatively rapid wear) with the continuous smooth rotation of centrifugals. The screw or gear pumps are in especially favorable service for petroleum products when the liquid handled lubricates itself; they are in unfavorable or improper service when handling water, since water is not a particularly acceptable lubricant in pumps where metal parts must rub against each other.

If a displacement pump outlet is throttled or closed, the pressure will increase until the power input is balanced, or until something breaks because of excessive pressure. Therefore boiler feed pumps, of piston type for example, that are run by steam engines, must have automatic governors. It is good practice to provide, close to the boiler, a valve that opens to admit make-up water to the boiler when the water level lowers, and that closes when the water level in the boiler reaches the desired high level. If the boiler feed valve closes, the water pressure in the pipe between the pump and the boiler must increase. Responding to this increased pressure, a throttling valve in the steam supply pipe for the boiler feed pump may close. The valve may be operated by a metal bellows or by a flexible diaphragm.

If a centrifugal pump outlet is throttled or closed, the pressure will increase until the power input is balanced or until the design character of the physical construction of the pump and its speed are satisfied. Beyond that point a centrifugal pump merely revolves without accomplishing any particular work and at the expenditure of inconsequential power. Centrifugal pumps, like centrifugal fans, require power input roughly proportional to the amount of material they transport, and thus consume more power if they move more material when resistance to flow is reduced. If the resistance to flow becomes higher, the volume of material moved decreases, and the power input decreases proportionally.

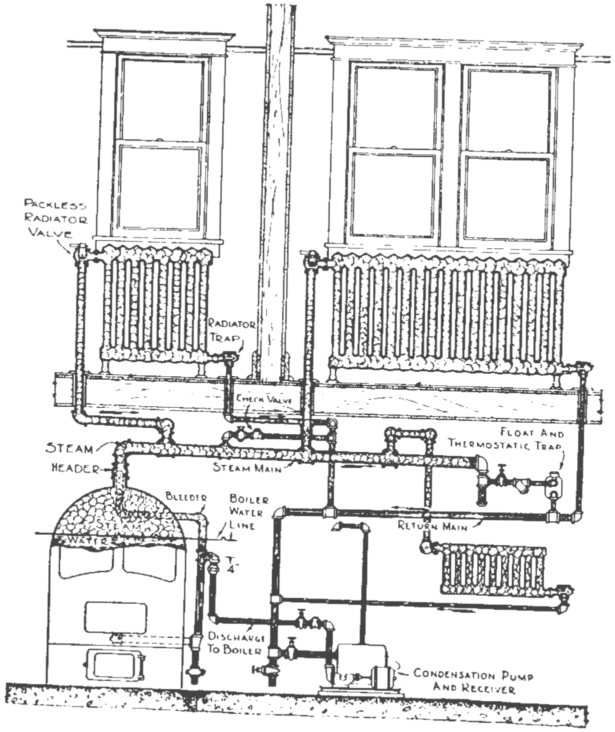

FIG. 3. STEAM HEATING SYSTEM IN WHICH STEAM PRESSURE MUST FORCE AIR OUT THROUGH THERMOSTATIC TRAPS

The temperature at which liquid water changes to water gas or steam varies with the pressure. Thus a description of a modern high-pressure steam boiler usually is not complete without mention of both the steam pressure and the steam temperature, which latter may be superheated beyond that corresponding to the pressure. The characteristic of cold-water pumps in that they prefer to handle water only, has developed the need in steam heating systems for pumps that will handle both hot water and hot air. Steam as used for heating radiators in buildings, originally required delivery to the outlying or distant heat transmitters at several pounds pressure above atmospheric, so as to force out the air through a small valve on each radiator. In such a system the entire radiator must be heated to 228 deg. or so, in order to do any business.

Figure 3 illustrates a steam heating system in which the steam pressure must force the air out through the thermostatic traps at the return ends of the radiators. The end of the steam main also has a

trap at its end. These traps pass water and air but refuse to pass steam. The water, collecting in the receiver, lifts a float switch, starting the pump, which thereupon forces the condensate up into the boiler. The air escapes through the vent pipe shown above the receiver.

With this steam heating system, modulation of temperature to meet changing weather was possible only by alternate cooling and heating of the entire radiator. If the steam could be circulated at reduced pressure, its temperature could be lower and overheating of rooms in mild weather would be reduced. Pioneers in heating thus arranged to apply a pump on the return pipes of a steam heating system to remove the air, and to allow delivery of steam, to radiators distant from boilers, at atmospheric pressure or less and consequently at temperatures of 212 deg. or cooler. For example, if the steam can be circulated at an absolute pressure of 10 in. of mercury, or at 5 lb. less than atmospheric pressure, the steam temperature would be only 192 deg. Absolute pressure is the pressure above zero, or 14.7 lb. less than atmospheric. It generally is measured in inches of mercury necessary to balance it against atmospheric pressure. If we could maintain the steam pressure at 20 in. of mercury or about 4.7 lb. absolute, the temperature of the steam would be only 161 deg., and there would be fewer open windows in mild weather than if the steam temperature were 212 deg. or warmer.

Real economies in fuel are obtainable by circulating steam at sub-atmospheric pressure.

The original use of a pump to remove air from pipes and heat transmitters probably was of the jet type, in which a small stream of steam at relatively high pressure is permitted to enter a valve connected to the return pipe through a small tapered orifice and which by its velocity induces a strong suction that removes air and condensate from the return pipe. The original steam heating system of this type sought only to remove the air, through a thermostatically responding ⅛-in. air valve connected to each heat transmitter at the end of the radiator opposite the steam supply valve, the air valve being about 12 in. above the bottom. All these air valves were connected by a separate pipe system to the air exhauster that usually was placed in the boiler room. This rudimentary two-pipe improvement to a single-pipe steam radiator heating system did effect a measurable fuel economy, since it permitted circulation of steam at atmospheric pressure or less, helped quiet the noise of hissing open-air valves and reduced the water hammer that attends poorly vented steam pipes. The jet pumps used in this way, however, did not have very long lives, and the vacuum air vent system eventually gave way to a scheme in

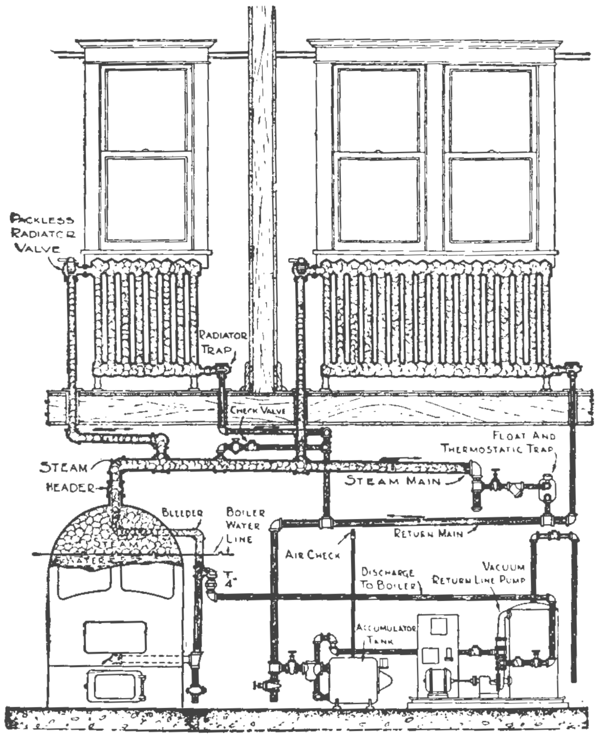

FIG. 4. TWO-PIPE VACUUM STEAM SYSTEM

which the condensate and air both were exhausted from the bottom of each heat transmitter through a trap connected at the end of the radiator opposite the steam supply valve.

Figure 4 shows such a plant. The simple condensate pump has been replaced by one that removes both the air and the water from the receiver and discharges the air against atmospheric pressure. The traps originally had float valves to pass water, and tiny openings to by-pass the air around the float valves. Eventually they were made to respond, as at present, to temperature variation rather than merely to accumulation of condensate. The jet-type exhaust pump was superseded by a reciprocating piston vacuum pump having a large diameter cylinder that could take both the air and the water passed through the traps.

The early reciprocating vacuum pumps followed the principle of the pitcher pump, except that usually the cylinder was horizontal, and was double-acting, with the discharge valve for each end in a

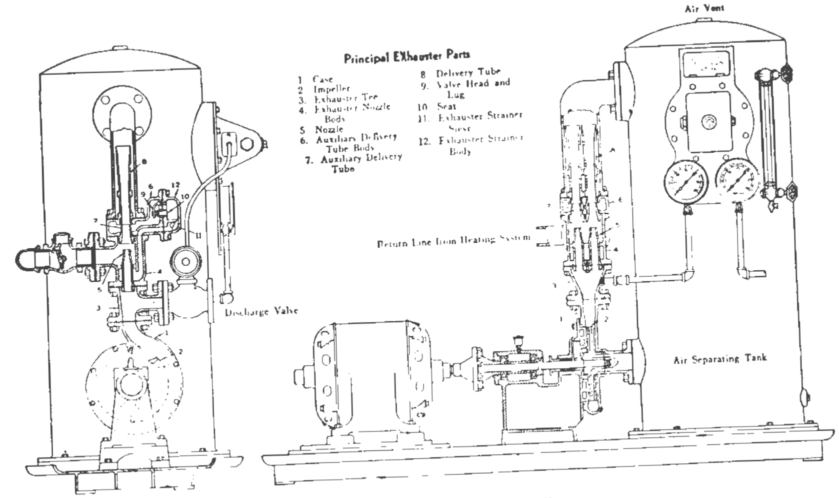

FIG. 5. DUNHAM VACUUM PUMP

separate chamber with several poppet-type valves in groups for suction and discharge rather than with the single valve of the pitcher pump.

Probably the first vacuum pumps were driven by high-pressure steam. They were decidedly inefficient as heat engines, since they ran at low speed and in many plants could not maintain sub-atmospheric pressure without cold water jets in the suction strainers near the pump inlets, so as to condense the vapor that came through the return piping along with the condensate and air and that emerged from the hot condensate when the pressure above it was reduced. Soon there were developed electric vacuum producers. One kind operated on the jet pump principle. A centrifugal hot water pump circulated part of the condensate through a tapered orifice into a tank, the jet reducing the pressure in the return pipe of the heating system. The present Dunham vacuum pump (Fig. 5) operates on this principle and the Dunham low positive pressure and temperature heating system has achieved remarkable economies as compared with single-pipe air-vent steam heating systems. Sometimes a second centrifugal pump is employed to deliver into the boiler the condensate discharged from the jet pump, especially when the boiler steam pressure exceeds about 15 lb. Any vacuum pump may be used in connection with the preliminary accumulator shown in Fig. 4. Another type of electric vacuum pump forces part of the water around the inside of an elliptical housing in such manner as to induce suction through the central inlet as the whirling

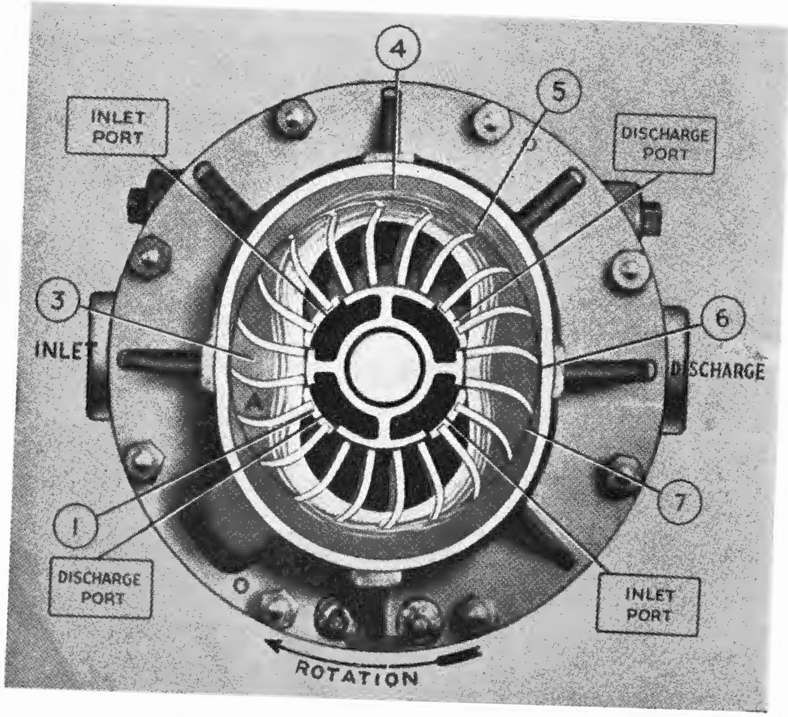

FIG. 6. OPERATION OF THE DUNHAM PUMP

water reaches the greater diameter of the ellipse and to induce pressure as the water reaches the smaller diameter of the ellipse.

In Fig. 6 the many-bladed rotor whirls freely with the ends of the blades immersed in the liquid. The blades and their end closure shrouds and the whirling liquid form a series of pockets which change in size as the liquid is forced closer to the shaft in the narrow diameter of the ellipse, and as the liquid recedes from the shaft in the wide diameter of the ellipse.

At A the chamber (3) is full of liquid and the pocket at A is full. At 4 the liquid has followed the curve of the ellipse, pulling air through the inlet from the heating system. At 5 as the ellipse narrows, the liquid is forced into the pockets and the air is compressed in the pocket, to be expelled through the discharge port. Condensate that enters with the air and that exceeds in volume that which can pass the narrow diameter of the ellipse, also is forced out. The cycle occurs twice during each revolution of the rotor.

This vacuum pump also can deliver the condensate directly to the heating boiler in case the steam pressure within the boiler does not exceed about 30 lb.

Centrifugal vacuum pumps frequently are driven by low-pressure steam turbines; in this case, power for the pump is obtained by utilization of a relatively slight pressure difference maintained between the steam in the boiler and that in the heating system.

Hot condensate is always reluctant to be lifted by atmospheric pressure from low-lying return pipes to the suction inlet of vacuum pumps. The water prefers rather to change its state to vapor, the elastic gas that pumps find it difficult to handle. An accumulator tank as in Fig. 4 may be provided for such plants. This is a relatively small reservoir below the lowest return main arranged to receive the condensate and air near or in its top. The suction pipe going to the vacuum pump is connected near or in the bottom of this tank. There is an air vent between the top of the tank and the pump inlet. When enough condensate collects in this tank, a float, lifted by the water, closes the electric switch for the vacuum pump motor. The pump thus may remove the accumulated air and may receive an intermittent charge of water which it delivers into the boiler; being stopped only by the float switch when the accumulator tank has been drained.

Owing to limitations in temperature control, to corrosion difficulties, and to many other peculiarities of steam heating systems, there is a decided tendency toward substitution of warm water as a heat carrier. This is especially desirable in cases where electric energy is available for circulating the water. Perhaps the simplest scheme is to pump the water directly through the boiler and thence through small pipes to the heat transmitters. The pump may operate intermittently in response to a strategically located thermostat. A weighted flow-control check valve is necessary to prevent thermal or gravity circulation of the water when the pump is not running. Another control arrangement, generally preferred, calls for operating the electric circulating pump continuously, with a water-mixing valve in the boiler-pump circuit. This valve, responding to a thermostat that senses indoor temperature or that may sense outdoor temperature, varies the relative volumes of recirculated water (water that by-passes the boiler) and hot water that goes through the boiler. The water in the boiler is always hot and ready to serve but the fuel consumption is proportional to the heat demand at the heating system, while the temperature in the heated rooms remains relatively constant without wasteful cycles of overheating and uncomfortable cycles of chilliness.

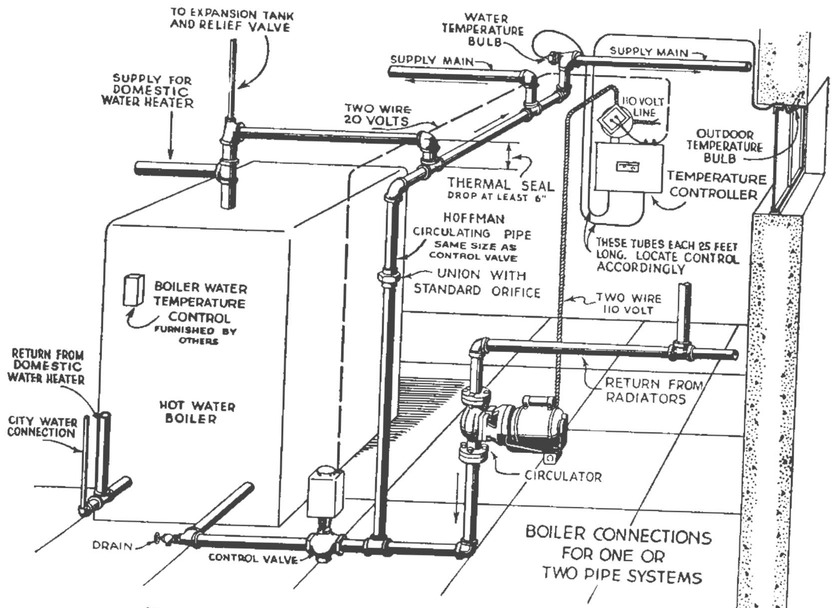

Fig. 7. Control Arrangements for Mechanically Circulated Hot Water Heating

The water in such a liquid heating plant may be warmed in different ways, as by flowing directly through a boiler that burns coal or oil or gas, or as by flowing through copper tubes that are surrounded by steam or by water at higher temperature than that desired in the radiators.

The Hoffman Specialty Company control arrangements for mechanically circulated hot water heating are shown in Fig. 7. The control valve responds to an outdoor temperature through the thermostat at the window and also to the delivered water temperature through the thermostatic bulb in the supply main. If both instruments agree that more heat is needed, the control valve permits water to enter the boiler and correspondingly permits hot water to flow from the boiler into the supply main. If the water in the supply main as a result becomes warmer than the pre-set temperature, the control valve closes, and the water from the return main is pumped directly into the supply main.

The arrangement has many advantages, particularly in that it changes the heat input to the rooms in a gradual manner, without violent and rapid fluctuations. When applied to buildings that have many rooms of different heat-losing characteristics, it is difficult to

find a location for a single thermostat that controls the rate of fuel consumption.

If, however, the principal control is out-of-doors, so that the heat delivery to the building is in inverse proportion to the outdoor temperature, and if the heat transmitters in the rooms are well proportioned, excellent results are obtained. The thermostatic bulb in the supply main acts as a safeguard not only against overheating but also against freezing. The fire intensity is governed by a thermostat in the boiler water, so as to keep hot water always available, but if the main valve in the return to the boiler from the pump is closed, there will be little waste of fuel.

If a centrifugal pump must have a suction lift, the end of the suction pipe should extend at least three feet below the surface of the water, and the pipe should slope upward all the way to the pump inlet and never downward after forming a hilltop in the suction line. The air that would be trapped in such a hilltop will make it difficult to maintain the sub-atmospheric pressure that is so necessary in permitting atmospheric pressure to force the water up to the pump. A gate valve and a check valve should be installed in the discharge pipe close to the pump, the check between the gate and the pump. Never place a check valve in the suction pipe of a pump above the water line of the reservoir or well from which the water supply is taken. The only satisfactory location for a check valve, to keep the suction pipe of a pump full of water, is under water at the bottom of the suction pipe, in which case the check is called a foot valve.

Always turn the impeller of a new centrifugal pump manually before applying power, to make certain that clearances are free and that the shaft packing is not binding the shaft.

Do not operate a centrifugal pump dry for any length of time. The casing should be filled with water, and the air should be forced out by unscrewing the plug that usually is installed in the top of the volute shell. The gate valve in the discharge pipe should be kept closed until the pump reaches full speed; then the valve may be opened gradually. Be sure that the direction of rotation is correct. Packing for the pump shaft should be installed in individual rings, each ring breaking joint with the next one. Do not over-lubricate ball bearings with grease under pressure. There is usually a screwed plug under each ball-bearing housing on pumps and motors. This plug should be removed when forcing grease into a ball bearing, so that the old contaminated grease shall be displaced by the new lubricant.

The catalogs of most pump manufacturers include tables of friction loss per 100 ft. in length of piping of standard sizes, and also show the equivalent lengths of pipe to be added in calculating the resistance to flow for various pipe fittings and valves. By aid of these tables it is easy, given the volume of water to be delivered, to compute the friction head of any piping system and from this to select the desired pump. For measuring the pressure to be overcome by a pump the common unit is a vertical foot of head.

All self-respecting pumps are rated by actual test, and their performance curves are published by the manufacturers. The descending output curve of a well-designed pump in relation to the power input crosses the rising curve of power at about the center of the zone of recommended duty.

A vacuum heating system pump serving a plant of 10,000 equivalent sq. ft. of direct steam radiation can be expected to require a 1½-h.p. motor when handling 15 gal. per min. of water, simultaneously with 5 cu. ft. per min. of air, maintaining enough sub-atmospheric pressure to sustain a column of mercury 10 in. high and while delivering the hot water into a boiler against as many as 20 lb. pressure. Allowing for resistance of fittings, valves and pipe as friction, this pump will serve a 100-h.p. boiler that operates at 15 lb. steam pressure.

The suction lifting ability of a pump is reduced approximately 1 ft. for every 1000 ft. of altitude above sea level. The same pump that develops a suction lift of 20 ft. at sea level will lift only 10 ft. when on a mountain 10,000 ft. high.

It is interesting to observe that the work of pumping gasoline is similar to that of pumping hot water, in that the vapor pressure and the temperature enter potently into the capacity of the pump on the suction side.

When the air pressure above water in an air-tight vessel is reduced, as by any type of pump capable of handling both air and water vapor, part of the water changes state from liquid to vapor. The heat necessary for this change may be taken from the remaining water. It is practicable in this way to reduce the water temperature in a well-insulated tank to about 40 deg. at an absolute pressure of 25 in. of mercury, and to use this chilled water for absorbing heat from buildings. Advantage is taken of water chilled in this manner for cooling several Chicago office buildings. Water vapor refrigeration has also been employed in cooling railway trains, using steam from the locomotive through jet pumps to deaerate the water.

There is a rather interesting example of the great differences in pump performance with varying suction and temperature conditions. They are from tests made by Mr. H. L. Ross of the Allis Chalmers Manufacturing Company.

Figure 8 shows four duplicate centrifugal pumps all handling 1000 gal. per min. against a head of 250 ft. The effect of a change in suction lift — that is, the distance from the surface of the water to the center of the pump and that of the vapor pressure (which with water is profoundly affected by temperature) — is striking. If the water is hot, the result is the same as though the suction lift were increased by an amount equal to the vapor pressure in feet of water.

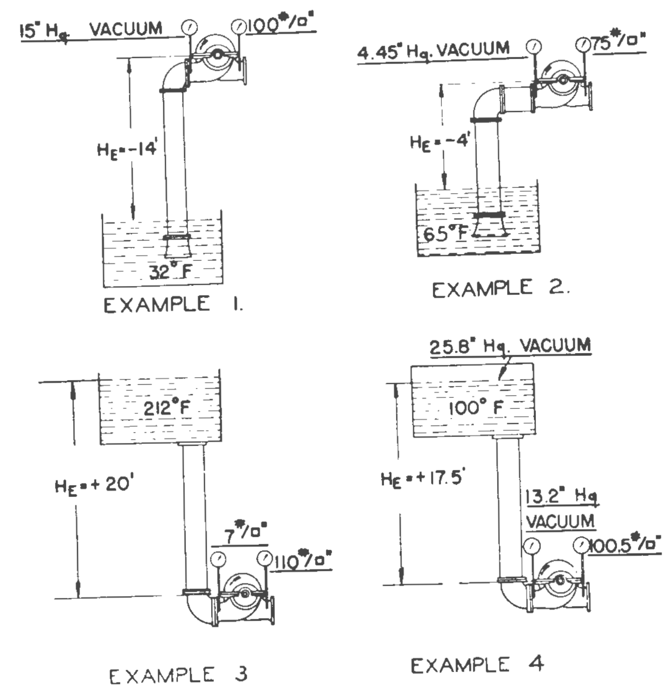

Fig. 8. Four Duplicate Centrifugal Pumps — Part I

EXAMPLE NO	1.	2	3	4
TEMPERATURE °F	32	65	212	100
SPECIFIC GRAVITY SP GR	1 0	72	955	995
VAPOR PRESSURE P_V PSI ABS	0 (APPROXIMATE)	7 2	147	95
PRESSURE AT SURFACE P_A	14 7 P S I ABSOLUTE (BAROMETER)	147 P S I ABSOLUTE (BAROMETER)	14 7 P S I ABSOLUTE (BAROMETER)	25 8"Hq VACUUM OR 2 P S I ABSOLUTE
SUCTION PIPE FRICTION H_F (FT)	1	1	1	1
STATIC SUCTION HEAD H_E (FT)	−14	− 4	+20	+17 5
SUCTION VELOCITY HEAD $\frac{V_S^2}{2g}$ (FT)	2	2	2	2
SUCTION GAUGE READING (FT)	$-15"Hg \times \frac{113}{1} = -17$	$-4\ 45"Hg \times \frac{113}{72} = -7$	$7" \times \frac{2\ 31}{955} = 17$	$-13\ 2"Hg \times \frac{113}{995} = -15$
TOTAL SUCTION LIFT (CALCULATED) $H_S = H_E - H_F$ (FT)	−14 − 1 = −15	−4 − 1 = −5	20 − 1 = 19	$-25\ 8"Hg \times \frac{113}{995} + 17\ 5 - 1 = -13$
TOTAL SUCTION LIFT (TEST) H_S = GAUGE $+ \frac{V_S^2}{2g}$ (FT)	−17 + 2 = −15	−7 + 2 = −5	17 + 2 = 19	−15 + 2 = −13
DISCHARGE GAUGE READING (FT)	$100" \times \frac{2\ 31}{1} = 231$	$75" \times \frac{231}{72} = 241$	$110" \times \frac{2\ 31}{955} = 265$	$100\ 5" \times \frac{2\ 31}{995} = 233$
DISCHARGE VELOCITY HEAD $\frac{V_D^2}{2g}$	4	4	4	4
TOTAL DISCHARGE HEAD (FT)	231 + 4 = 235	241 + 4 = 245	265 + 4 = 269	233 + 4 = 237
TOTAL HEAD (DISCH − SUCT) (FT)	235 − (−15) = 250	245 − (−5) = 250	269 − 19 = 250	237 − (−13) = 250
NPSH (CALCULATED) $= \frac{2\ 31(P_A - P_V)}{SP\ GR} + H_E - H_F$ (FT)	$\frac{2\ 31(147-0)}{1} - 14 - 1$ = 34 − 15 = 19	$\frac{2\ 31(147-7\ 2)}{72} - 4 - 1$ = 24 − 5 = 19	$\frac{2\ 31(14\ 7-14\ 7)}{955} + 20 - 1$ = 0 + 20 − 1 = 19	$\frac{2\ 31(2-95)}{995} + 17\ 5 - 1$ = 25 + 16 5 = 19
NPSH (TEST) $= H_S - \frac{H_{VP} - (14\ 7)\ 2\ 31}{SP\ GR}$ (FT)	$-15 - \frac{(0-14\ 7)\ 2\ 31}{1}$ = −15 − (−34) = 19	$-5 - \frac{(72-14\ 7)\ 231}{72}$ = −5 − (−24) = 19	$19 - \frac{(14\ 7-14\ 7)\ 2\ 31}{955}$ = 19 − 0 = 19	$-13 - \frac{(95-14\ 7)\ 2\ 31}{995}$ = −13 − (−32) = 19

Four examples illustrate duplicate pumps working under the same hydraulic conditions — that is 1000 gpm against 250 ft head with 19 ft npsh. These pumps will have exactly the same characteristic curve with head in feet, and all will break off at exactly the same capacity. Readings have been corrected to the centerline of the pump.

FIG. 8 (CONCLUDED). FOUR DUPLICATE CENTRIFUGAL PUMPS — PART II

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